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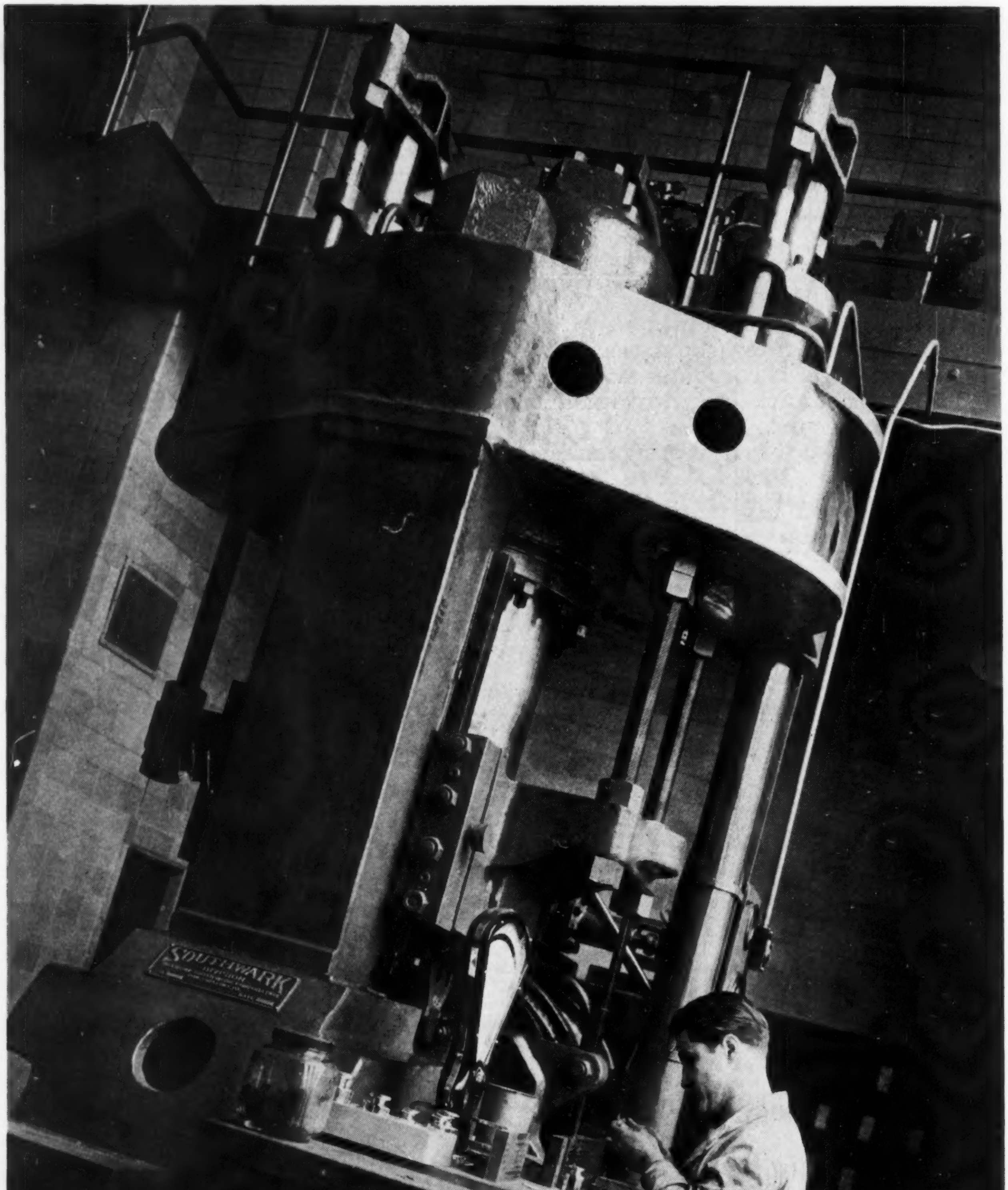

Courtesy Firth-Sterling Company

400-Ton Two-Way Press

(In this press powders are compacted into the shape approximately 20 per cent larger than the finished blanks or nibs. Pressures range from 4000 to 6000 pounds per square inch. See paper on "Powder Metallurgy," pp. 801–806 of this issue.)

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No. 11

MECHANICAL ENGINEERING

November
1938

GEORGE A. STETSON, *Editor*

A Cross Section

IN THE memorial biographies of deceased members of The American Society of Mechanical Engineers, issued in October, for the year 1938, will be found a miniature cross section of the lives of mechanical engineers. Here may be read brief stories of the lives of obscure as well as famous men, of engineers who lived to experience the leisure that comes to some, and of youths whose work was cut short before it was fairly begun. Reading not one but many of these sketches, one can visualize the great variety of training and attainment that marks the lives of engineers, and the tremendous sweep of experiences that are associated with the work they do. Here is no group of idealized careers in which virtue and hard work are inevitably rewarded and a plan, laid out with intelligence in youth, unfolds as predicted with the passage of years. Here are actual cases of situations in which real men found themselves, and here may be sensed what resulted from those situations for the men who faced them.

It is inspiring to read the life of George Westinghouse. Every young engineer ought to feel that within himself lies the potential Westinghouse of his own day. But perhaps he also ought to read at least one year's grist of A.S.M.E. memorial biographies. He will find much that will strengthen his purpose, forearm him against hazards, and teach him humility.

Powder Metallurgy

TAKE a measured amount of iron in finely powdered form, if you want a small gear; or of tungsten-carbide and cobalt, if you want a cutting-tool bit; or of copper, tin, and graphite if you want a bearing; or of silver if you are the Mint and want quarters or half dollars; place in a mold; apply pressure and heat in the proper manner; and you have a product made without waste of material and without casting or machining. Such, in rough outline is powder metallurgy. For further details, see this month's leading article.

Most engineers are familiar with the uses to which electrical engineers and cutting-tool manufacturers have applied powder metallurgy for metals of high melting point. From time to time references to powder metallurgy have appeared in papers in Mechanical Engineering, or abstracts of articles on the subject have been presented. Now, for the first time, a paper, devoted exclusively to powder metallurgy, is offered. It will repay thoughtful reading, for the applications of powder metallurgy are growing rapidly.

Powder metallurgy will appeal to two classes of engineers. It will appeal to every engineer who has a product or a part about which the question can be reasonably asked: Can it be made better or more cheaply by the powder-metallurgy technique? This is the kind of a question that is always asked when a new material or a new method of fabricating an old material is developed. It will also interest manufacturers of machinery and equipment necessary to carry out the processes involved. In this connection Mr. Comstock, when he presented the paper at Providence, threw out a challenge to mechanical engineers competent to design presses to be used in the process. New processes mean not only new products but new machines as well.

Professional Divisions Conference

SOME months ago it was announced in these columns that The American Society of Mechanical Engineers would inaugurate at its 1938 Annual Meeting a conference of representatives of the Society's professional divisions with the object of considering technical problems in the same kind of a nationwide forum that has existed in the Local Sections Group Delegates Conference for the discussion of Society affairs. Plans for this new conference were advanced at the September 28 meeting of the Committee on Professional Divisions when the time was set at 9 o'clock, Monday, December 5, and subject matter to make up the agenda was discussed.

In setting up this new kind of a conference the Society is embarking upon a significant course of technical development that attests its vision and vigor and that would do credit to the zeal and enthusiasm of a newly organized group of engineers determined to carve out for itself an important niche in the gallery of technological development. It was typical of the Society in the early days of its formation, as it has been at many periods during the last half century, that it gave its chief concern to trends in mechanical-engineering development and to the dissemination of engineering knowledge. In the early eighteen-eighties the Western World was in a fever of industrial and scientific development. This country, under the impetus of the Philadelphia Centennial Exhibition, was making applications of science to industry that assisted in ever-advancing westward expansion

and was providing new and useful goods and services, and was contributing to the markets and manufacturing technique of Europe as well. Looking back at what now appear to have been unparalleled opportunities for engineers, it is easy to see why the Society came into being and why it prospered as it did. But today—

Today engineers are on the threshold of even greater opportunities than they faced in 1880, and to develop these opportunities they are infinitely better prepared than they were when a handful of them organized the A.S.M.E. What did R. H. Thurston, first president of the Society talk about in his memorable addresses? Was it about a technological and scientific world in which man's ingenuity had lost its skill? He directed the attention of his fellow engineers to the progress they were making and outlined for them the possibilities that lay in the future, most of which have since become commonplace realities.

Today, conditions are not the same as they were in 1880, but the spirit of men to cast their engineering thinking forward into the immediate future still lives. The setting up of the new professional divisions conference is an embodiment of that spirit. It should be hailed as a great intellectual reawakening to the spirit of Thurston. It must not be allowed to bog itself down in unimaginative inertia. It calls for a high quality of leadership. It must be made to succeed!

National Defense

IT IS a sad commentary on contemporary affairs that the present state of peace in the Western World, so dramatically saved from extermination during the dark days of September, gives rise not to disarmament but to military defense and preparedness on an ever-increasing scale. People do not want war and will go to great lengths to avoid it. Fear of the threat of force, however, has not been allayed by the meeting at Munich. Indeed, it has been enhanced, not only by the course of affairs among nations, but by technological changes in the art of war that make areas formerly remote from the battlefield subject to destruction, and that place non-combatants and the responsible heads of governments in jeopardy never before so real. Moreover, although war unifies national purpose, in a manner more effective than most of the very few "moral equivalents" that have been found for it, internal dangers are known to be as destructive as external ones, for the threat of civil strife, revolution, and anarchy must always be faced. The realist, therefore, who wishes to keep his country free from the aggressive acts of other states and to preserve tranquility, prosperity, and happiness at home, will be an advocate of preparedness.

It is fortunate that up to the present we have not found it necessary to resort to conscription, to build Maginot lines, to maintain a merchant marine for the purpose of keeping ourselves supplied with food, to equip every citizen with a gas mask and train him in air-raid precautions, or to be ready for overnight mobilization. But we must keep well armed, as the Honorable Louis Johnson, Assistant Secretary of War, said in the concluding paragraph of his address, "Industry Aids the Army," presented at the 1938 National Fall Meeting of The American Society of Mechanical Engineers. Secretary Johnson's address will be found on page 882 of this issue. It is a tribute to the cooperation between the Army and industry in preparation of an industrial mobilization program.

Secretary Johnson spoke of surveys, conducted by the Army, of all of our principal plants and factories, as a result of which, he said, "we feel that with proper education industry can carry a major war load and take care of our civilian as well as our military needs in time of emergency. . . . . We have earmarked ten thousand plants for war production. We have informed their managers and their proprietors as to the tasks to be imposed upon them in the event of war. All of them have expressed their ability to assume the task."

It is fortunate for this country that, as the Secretary said, "the whole nation is cooperating wholeheartedly with the War Department toward the realization of its industrial mobilization program." Events abroad have shown us how fortunate we are that the program was initiated some time ago, for we are that much better equipped to deal with the realities of unwanted emergencies. And it is gratifying that the Secretary could say to the Society as he did: "Your National Defense Division has freely given us its advice on many difficult technical matters. . . . . The War Department appreciates your many efforts. For my own part, I particularly value your mental attitude toward all engineering problems and I trust that more and more we of the Army will come around to your view on industrial engineering. . . . . I am inclined to the general view that what private industry can make should be the deciding factor of what the Army can use, and what private industry makes best is exactly what the Army must use."

A.E.C. Forum

THE second forum of the American Engineering Council, jointly sponsored by the Michigan Engineering Society, will be held at the Hotel Statler, Detroit, on November 11, 1938, and the subject for discussion is to be "Invention and the Engineers' Relation to It."

An imposing list of speakers has been prepared: Dean H. B. Dirks, president Michigan Engineering Society, Frederick A. Allner, chairman A.E.C. Public Affairs Committee, Kenneth H. Condit, assistant to the president of the National Industrial Conference Board, Dr. Lyman J. Briggs, director of the U. S. Bureau of Standards, T. A. Boyd, of the General Motors Corporation, Harry H. Semmes, chairman of the patents committee of the American Bar Association, and Dr. Frank B. Jewett, vice-president American Telephone and Telegraph Company. Dr. William McClellan, president A.E.C., will act as chairman of the evening session and will sum up the discussion at the end of the evening.

POWDER METALLURGY

Its Increasing Importance to Industry

By GREGORY J. COMSTOCK

HANDY AND HARMON CO., BRIDGEPORT, CONN.

THE FABRICATION of objects from metal powders is not a new art. It has recently become a matter of general interest, however, as a result of the striking characteristics of its later products. The possibilities which it presents for further development are now beginning to be thoroughly investigated.

HISTORY OF DEVELOPMENT

In the beginning of the nineteenth century, platinum melting presented many difficulties (1).[1] These were associated not only with the fairly elevated melting point of the metal, 1755 C, but with its tendency to become contaminated with furnace gases when in its molten state. Platinum powder could, however, be obtained at that time in a fairly pure state by precipitation and reduction. Early investigators found that pressing this powder into the form of small billets and heating them to a temperature which was several hundred degrees below the true melting point of the metal resulted in the consolidation or sintering of the mass to an extent which would subsequently permit satisfactory hot forging. During the heat-treatment which was applied to the pressed powder, the individual particles of which it was composed apparently became fused or welded at their points of mutual contact. Repeated forging and heat-treatment continued this bonding between particles and resulted in a dense, strong, but ductile metal from which articles could be fabricated in a manner precisely similar to that which was applied to the cast material. Casting with its attendant difficulties and contamination was rendered unnecessary. The process was also applied to iridium.

The economic desirability of producing thin filaments of metallic tungsten for electric lamps was urgently presented in the beginning of the twentieth century. The casting and contamination difficulties which were incident to the manipulation of that extremely refractory metallic element undoubtedly suggested the employment of means which were similar to those which had earlier proved so eminently satisfactory for platinum under similar circumstances. Metallic tungsten in powder form was also available by precipitation and reduction. It, too, was found to be capable of consolidation by the application of heat to billets which were pressed from the powder. The true melting temperature of the metal, 3400 C, was not required for promoting particle-to-particle welding in such billets. Hot forging the forms which had been heat-treated in this manner improved their strength and ductility to an extent which ultimately permitted their cold deformation by modified wire-drawing practices. By these means the finest of wires were ultimately produced from the most refractory of metals (2, 3).

Possibly a hundred years elapsed between these two primary applications of powder metallurgy. The names of those who were responsible for the development of the original platinum-powder process have unfortunately not been handed down to us with any degree of authenticity. The names of Cooledge, Jeffries, Benbow, and others are associated with the later technical and commercial application of the powder manipulations which are now employed in the large commercial production of ductile tungsten filament wire.

The powder process for making objects of platinum was of more or less transient value. Furnaces improved, higher temperatures well above the melting point of platinum as well as controlled atmospheres became readily obtainable, and the powder process was no longer essential for the production of high-grade platinum.

The development of ductile tungsten by the processes of powder metallurgy, however, represented a major commercial achievement for which there was an immediate, urgent, and protracted demand. It may almost be said to have founded an industry. It has resulted in a general application of the powder process for the production of filament wire and from it has grown a familiarity with metal-powder technique which has led to the discovery of other valuable metal-powder products. It is quite natural that most of these later materials have had their inception in the electrical industry where the technique and equipment for effectively fabricating metallic powders was first developed and employed on a commercial scale.

At the present time there are four principal commercial products which are being manufactured in quantity from metallic powders (4). These are: (*a*) the refractory metals tungsten, molybdenum, and tantalum; (*b*) electric contact and electrode materials; (*c*) the porous bearings which are being so generally applied to a wide variety of uses; and (*d*) the hard cemented carbides which are used as tool and die materials. All of these display strikingly unusual characteristics and each has been responsible for a notable advance in the field of its particular application.

THE REFRACTORY METALS

The production of metallic forms of molybdenum and tantalum has in general followed the manipulations which were applied to ductile tungsten with such variations as their individual characteristics indicated as being necessary. Ductile forms of tantalum were particularly difficult of achievement because of the extremely recalcitrant character of that most peculiar of the metals. Credit for this accomplishment belongs to Dr. Clarence W. Balke who persevered in his experiments long after anyone else would have decided the production of commercial forms of tantalum was an impossibility. The availability of these metals in the form of sheet, strip, rod, wire, and fabricated articles has led to useful and important improvements in the chemical, electrical, and communication fields.

MATERIALS FOR ELECTRIC CONTACTS AND ELECTRODES

Metal-powder contact materials for electric-current interrupting and electrode applications, in general, owe their develop-

[1] Numbers in parentheses refer to Bibliography.

Contributed by the Iron and Steel Division and presented at the Fall Meeting, Providence, R. I., October 5–7, 1938, of The American Society of Mechanical Engineers.

ELECTRIC CONTINUOUS MESH BELT SINTERING FURNACE, SINTERING DUREX BEARINGS USED IN AUTOMOBILES

(*Courtesy Moraine Products Division, General Motors Corporation*)

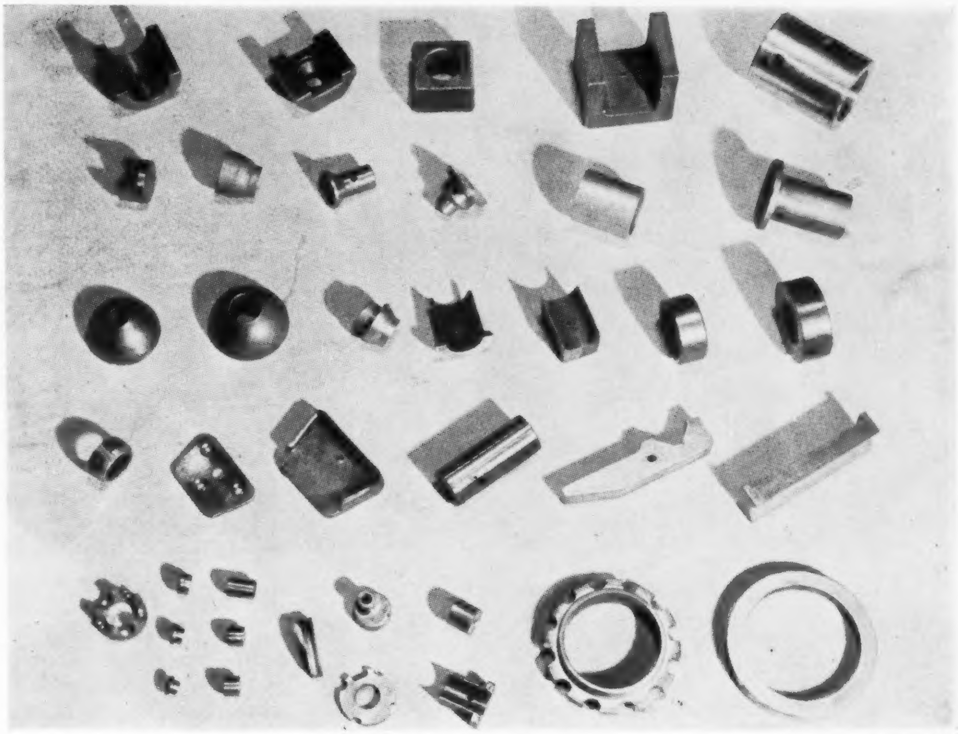
ment to one interesting effect which is peculiar to metal-powder products. This relates to the composite physical properties which these fine aggregates display. Alloys which are produced by the more normal melting and casting process, generally possess properties which are inherently their own rather than those of the metals from which they were originally made. For example, brass has definite physical characteristics of its own which are dissimilar either to those of the copper or the zinc which were used in forming the alloy.

Certain of the powder products, however, which are made without diffusion alloying, display the original characteristics of their component metals in almost direct proportion to their presence in the composition. This is true of powder combinations of copper with tungsten, or silver with nickel, tungsten, molybdenum, or graphite. Advantage is taken of this phenomenon in applying these materials to circuit breakers, welding machines, or other electrical devices (5). The efficiency of many of the early electric-welding installations was seriously decreased because of the tendency of the electrodes, which carried the heavy welding current, to fuse and pit in service. An intensive search among the alloys which were available for such applications did not satisfactorily remedy this condition. In summing up the problem it was ascertained that a material having some of the refractory character of tungsten and at least a portion of the thermal and electrical conductivity of copper was required (6). Powder mixtures of these metals, consolidated by heat-treatment displayed these properties in an easily regulatable manner and effectively solved the difficulty. Circuit-breaker contacts can display no tendency to stick or weld together in service without seriously impairing the safety features of these important electrical devices. Heavy current, arcing at the moment of interruption, promotes fusion and sticking unless extremely refractory metals which possess relatively poor conductivity are used as contacts. In certain applications where such resistance and the heat which is generated because of it are undesirable, metal-powder aggregates have proved to be indispensable.

Here again the conductivity of one metal component is maintained to a regulatable degree by combining it with balanced proportions of another component which in turn maintains its own nonwelding characteristics in the aggregate. Silver is used as one component because of its high electrical and thermal conductivity and because its oxide is unstable at relatively low temperatures. Nickel, molybdenum, or tungsten are combined with it because of their nonwelding and high melting characters. Graphite is combined with silver because its antifluxing action mechanically prevents welding. It is interesting to consider that these particular combinations of metals, or metal with the metalloid carbon, have no particular affinity for one another and, as they do not form alloys, could not be produced by the normal melt-

ROTARY BRIQUETTING MACHINE MAKING SPHERICAL SELF-ALIGNING DUREX BEARINGS FOR SMALL ELECTRIC MOTORS

(*Courtesy Moraine Products Division, General Motors Corporation*)



A VARIETY OF SPECIAL SHAPES WHICH HAVE BEEN MADE BY POWER METALLURGY
(Courtesy Moraine Products Division, General Motors Corporation)

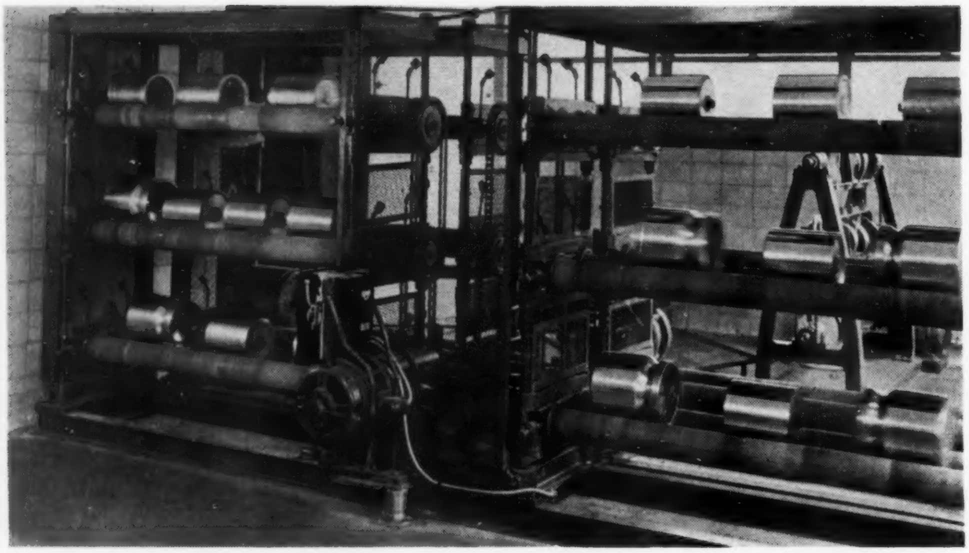
ing and casting process. Originally these materials were pelleted into contact forms from powders and sintered to promote sufficient adhesion between particles to prevent crumbling in service. In another method of preparing them they were impregnated with a minor proportion of the lower melting component in molten form (7). Recently a process has been developed and applied to certain compositions of these contact materials which enables them to be produced in ductile forms of sheet, strip, rod, and wire. Essentially it consists in pressing and sintering the powder compositions to promote the adhesion which was originally obtained in the previous process and then alternately mechanically working and heat-treating them until complete bonding between particles has been accomplished. When this has been done, the bonding of the powder particles closely resembles the intergranular bonding of cast products and the ordinary methods of further fabrication can usually be applied to them without hazard. Thin ductile sheets of contact material or bimetallic contacts combining these ductile powder contact materials with steel, copper, or other metallic bases are consequently available for economic application. The better bonding developed by this process is calculated to afford improvements in the physical and electrical characteristics of the materials which are produced in this manner. The development of metal-powder materials for contacts and electrodes has represented a highly specialized division of powder metallurgy. In patent literature covering its commercial development the names of Gebauer, Jennings, Gero, Iridel, Weiger, Hensel, Sieger, Zickrick, Adams, and many others appear as contributors.

POROUS-METAL BEARINGS.

The manipulation of metal powders permits the formation of unusual structural effects which it would not be feasible to produce by casting. The porous-metal bearing is an outstanding example of this fact and is one of the most important and far-reaching of the present applications of powder metallurgy. A great deal of careful and capable research and development have been applied to the processes which are now being employed for the mass production of these bearings. The finer points of their manufacture are at the present time surrounded with an understandable reticence even though the products themselves are protected by a patent structure. Essentially the bearings consist of copper, tin, and graphite, which are combined as powders with a lubricant and pressed to form. Heat-treating under conditions which promote diffusion and alloying between the copper and tin particles produces a regulated and continuous porosity. Subsequently they are exactly sized in suitable dies and impregnated with oil. Recently an iron or iron-copper bearing has been developed along similar lines for applications which involve excessively heavy pressures. The capillarity of these bearings conveys oil directly through the wall of the bearing to the bearing surface which insures an adequate supply of lubrication to all portions of the bearing. When necessary an additional supply of oil is automatically supplied to those portions which require it most. In some cases the oil with which the bearings are originally impregnated is sufficient to provide lubrication over the life of the machine into which it is incorporated. In other cases depending upon the speed and other factors, it is necessary to resort to the use of conventional means of lubrication to provide oil. Generally speaking, the life of the oil with which the bearing is impregnated is sufficient for several million revolutions. When this oil becomes exhausted the bearing may then be reimpregnated by conventional means. In the nonporous metal bearing the delivery of the lubricant to the bearing surface usually involves the operation of the movable portion of the assembly. Without such action the shaft rests upon the bearing which is dry at the point of contact until movement has proceeded for an appreciable time and has formed a film of lubricant. Wear is rapid until this film is formed and the rotating member separated from the bearing by it. The promotion of this film in the porous-metal bearing which delivers oil by capillary action is almost if not quite continuous. Sealed bearings in domestic appliances such as refrigerator units; inaccessible bearings, bushings, and shims in the automobile; the lubrication of textile equipment where excess oil constitutes a spoilage hazard; and countless other advantageous applications indicate its valuable contribution to general progress and its ever-increasing industrial application. Among those responsible for this development the names of Gilson, Williams, Bogehold, Langhammer, and Koehring should be mentioned.

CEMENTED CARBIDES

The hard cemented carbides (8, 9, 10) are possibly the most revolutionary and are certainly the most spectacular of the



A VIEW OF THE BALL MILLING ROOM SHOWING SOME OF THE UNITS IN OPERATION

(*Courtesy Firth-Sterling Steel Company*)

metal-powder products which have followed the development of ductile tungsten. Their advent and application necessitated profound changes in the previous conception of the limitations which were required for the machining of the metals and the drawing of metallic wires. In their present form they are characterized by their extraordinary hardness which is maintained at elevated temperatures and their unusual strength in compression.

Structurally they consist of minute particles of hard metallic carbide which are cemented to one another by a small quantity of an alloy which has been molten in one stage of the manufacture of the material. Tungsten carbide was first made in the electric arc and was found to be a superlatively hard and metallic compound. Cast from its elevated melting temperature, 2600 C, it is relatively brittle (11, 12, 13, 14). Pressed in powder form and heated in a technique similar to that which is applied in the ductile-tungsten process, it is also too brittle to be used to its fullest advantage as a tool or die material. It is, therefore, mixed in powder form with a minor proportion (6 to 13 per cent) of a lower-melting metal powder and is pressed and heated to a temperature which is sufficient to promote liquefaction of the lower-melting component. On cooling, this liquid cement solidifies and cements the carbide particles to one another. The product which results possesses the characteristics of both the carbide and of the matrix in almost direct proportion to their presence in the composition.

The present hard cemented-carbide compositions, therefore, essentially consist of a major proportion of a finely divided, hard metallic compound and a strong, tough, and thermally stable cement which must be present in minor proportions if the characteristics of the hard carbides are to be the dominating physical attributes of the finished material. The hard component must be hard, strong, and sufficiently metallic to permit its being strongly cemented by the welding or brazing action of the molten cement which is formed during sintering. Tungsten carbide was first employed as the hard component of these compositions because in powder form it combines a high metallicity with great strength and hardness. Its fine particles braze satisfactorily to one another with a molten alloy formed by cobalt which has dissolved certain small amounts of tungsten carbide while it was in a liquid state (15). Cemented tungsten carbide produced in this way satisfactorily cuts such crisp-cutting materials as cast iron at high speed and for long periods of time without displaying excessive wear (16). Similarly applied to machining annealed steel or other strong, tough, and plastic materials, however, it displays a tendency to seize and to weld to the chip at the hot point of contact with it. This results in the formation of a crater just behind the cutting edge and leads to the ultimate failure of the tool which must be excessively reground before it can be put back into service. Investigation has indicated that the highly metallic character of tungsten carbide which is so effective in promoting good cementing is in part at least a disadvantage when steel cutting is in question because it promotes contact welding between the hard cemented tungsten-carbide particles and the hot chip which is passing over them. To reduce this seizing tendency other hard carbides having lower metallicity or nonseizing characteristics have been employed (17). Tantalum carbide or titanium carbide have been used in this manner either alone or mixed with various proportions of tungsten carbide. Recently McKenna has, with great ingenuity, succeeded in producing a metallic compound combining tungsten and titanium in carbide form. This material has the formula $WTiC_2$ (18).

Although the point is a controversial one, it appears that hard carbides which are less metallic than tungsten carbide, are proportionately weaker than that material. Certainly the less-metallic carbides do not bond as satisfactorily in the present cementing routine. The substitution of these materials for tungsten carbide in hard cemented tool materials, particularly for application in cutting steel which necessarily involves the generation of greater stresses than machining iron or the nonferrous alloys, has consequently been attended by considerable difficulty and disappointment.

In their present form, however, hard cemented carbides have revolutionized the machining of many materials, and have afforded a tremendous improvement in the service which can be expected from wire-drawing dies. Many materials which have previously been regarded as being unmachinable are now being cut without difficulty by means of hard cemented carbide tools. The development and application of these metal-powder products represent an improvement which has not by any means been duplicated in the recent history of tool materials.

The hard-carbide tool and die business of this country at the present time involves more than five million dollars annually and must be regarded as still being in the early stages of its development.

Among the many who have been associated with this important field of powder metallurgy Schroeder, Strauss, Gilson, Hoyt, Sykes, Jeffries, Kelley, Balke, Schwarzkopf, McKenna, and Laise should be mentioned as important contributors to its development.

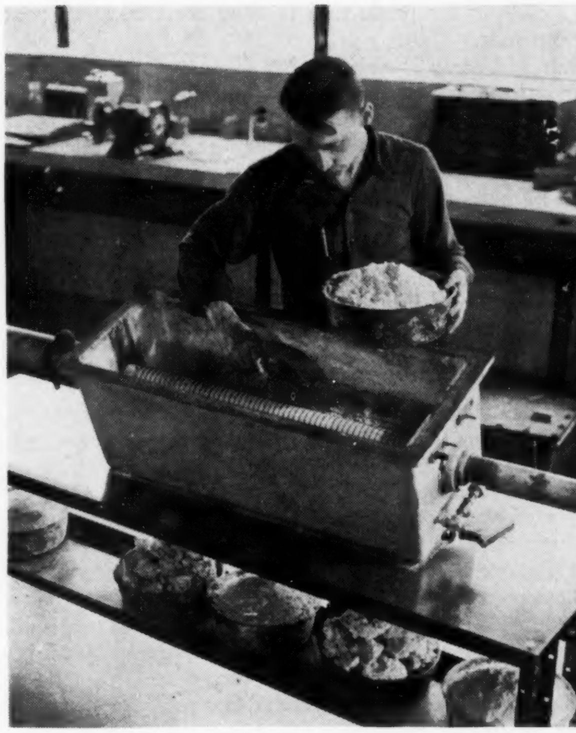
Even though the hard cemented carbides have already been

responsible for such radical improvements in tool and die applications, it is felt that metal-powder tool materials are as yet only in the preliminary stages of their ultimate development. The present method of manufacturing hard cemented carbides requires a preponderance of the powdered carbide and limits the binder to amounts which can be retained by the capillarity of the compacted refractory mass during the sintering period when the cement is molten. It is believed that other processes which are now in development will remove some of these composition limitations and that metal-powder tool materials will shortly become available which can be successfully applied to a much broader field than that which is now covered by the hard cemented carbides. The advantages of developing metal-powder products which would communicate some of the wear resistance and other characteristics of the hard carbides to cutlery and fine cutting edges is quite obvious. The difference in hardness, wear resistance, and cutting capacities which exists between the most efficient of the present cast tool materials and the hard cemented carbides in their present form is considerable. This intermediate field may include such important and much-used tools as blanking, striking, extrusion, deep drawing, forging, and forming dies, as well as a host of other tools which are too numerous to mention. The development of metal-powder intermediates having properties between those of the present cast products and those of the present hard-carbide materials for adequately covering this unimproved field of application is a challenge both to the powder metallurgist and the manufacturer of tool materials which is by no means being overlooked.

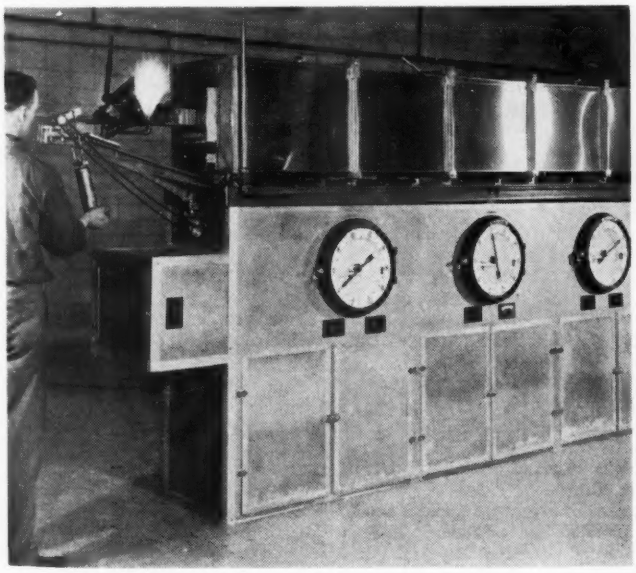
ADVANTAGES OF METAL-POWDER TECHNIQUE IN MANUFACTURING

A consideration of the four principal metal-powder products which are now being made in quantity indicates some, but by no means all, of the demonstrable special advantages which are made possible by the manipulations of metal powders. It indicates that such powder fabrication affords a means of avoiding the difficulties which are involved in processing metals which are too refractory to melt and cast in the normal practice; that fine metal aggregates displaying the individual characteristics of their metallic components can be produced by such means and that combinations of this kind are by no means limited to metals which display an affinity for one another. These commercial powder products also demonstrate the fact that unusual structural effects can be produced by powder processes which result in such valuable engineering adjuncts as the porous bearing and also that tool materials based on an entirely new conception of structure and composition can be made from powders and result in an increased efficiency of a high order of magnitude.

Alnico. One other product which is now in process of commercial production should be mentioned to illustrate another important possibility of powder metallurgy which has lately awakened a great deal of interest and gives promise of being of considerable industrial importance. The iron-aluminum-nickel-cobalt magnetic alloy of Ruder presents casting and machining difficulties which have hampered the application of this valueable improvement in permanent magnets. The alloy is not an easy one to cast without imperfections because of its composition and the castings themselves are so difficult to machine that they must either be ground or machined with hard carbide. Small magnets of involved conformation are therefore extremely expensive as a result of such casting and finishing difficulties. Many small alnico magnets are immediately required for use in meters and other small electrical devices. It has been found that they can be produced quite efficiently and less expensively from metallic powders. They are pressed to shape from the powders, alloyed by diffusion during the consolidating heat-treatment which is then applied to them and require little or no finishing after these operations have been completed. There is therefore evidence at hand that in some



PACKING THE HEATING CHAMBER OF A SINTERING FURNACE
(To sinter tungsten carbide a hydrogen atmosphere is essential. Special-designed furnace with Alundum tube, wound with resistance wire, is necessary to permit accurate control of temperatures.)
(*Courtesy Firth-Sterling Steel Company*)



CHARGING PRESSED BILLETS INTO A LOW-TEMPERATURE SINTERING FURNACE, AUTOMATICALLY CONTROLLED FOR TEMPERATURE, FLOW OF HYDROGEN, AND STOKING SPEED
(*Courtesy Firth-Sterling Steel Company*)

cases metal-powder production is more economical than are other methods.

Powder Molding. There are other advantages peculiar to the manipulation of powders which are similarly being commercialized. One of them has to do with the accuracy of sizing which powder molding permits. One of the large automobile manufacturers is producing small parts, molded from iron powders, bonded by heat-treatment, and re-pressed in sizing molds to precise dimensions. This is done in preference to machining castings to fine tolerances, both because a higher degree of accuracy and less variation from piece to piece is secured and because it is cheaper. It is felt that this possibility of powder manipulation will be subject to considerable commercial development.

THE PLACE OF POWDER METALLURGY IN INDUSTRY

The principal commercial products of applied powder metallurgy have long since passed through their experimental-development and introductory stages. They have demonstrated their commercial desirability and the practical advantages of the powder processes by which they are made. They have established an important and permanent place for themselves among the industrial materials which are available for commercial application. They are much in demand and are produced in adequate, well-established, and permanent manufacturing plants which are periodically being expanded to meet increasing demands for these products.

Each one of these materials was at first regarded with considerable doubt and skepticism which were engendered by the novelty of their character and performance and the unusual methods which were employed in their manufacture. As they became better known and powder processes were more generally discussed, two distinct reactions to the future fabrication of metal powders were observed. One group of enthusiasts, who possessed lively imaginations and were either unaware of or discounted the long years of laborious effort which had been applied to these materials before they represented a practical accomplishment, suggested as immediate commercial possibilities applications of powder metallurgy which would have required years of careful development before they could be realized in a practical way. Others adopted the negative attitude that these processes belonged in the electrical industry, that they were all tied up with patents, and that the expenses of pioneering investigations, development, and application were too great to warrant the serious consideration of applying powder methods to their products. Some of this latter group, led on by the enthusiasts, made preliminary trials of powder methods, found that they were not as easy or as finished as they had been led to believe and discontinued further work, feeling that they had given them a trial and had been found wanting.

Time has a way of rectifying the mistakes both of over-enthusiasm and of ultraconservatism. Processes or products which possess real value have without exception eventually been put to use in a rational and practical manner. Powder metallurgy will be so employed in the future by many industries which are now unaware of the changes in their manufacturing procedure which will eventually take place.

TUNGSTEN CARBIDE TIPS WHICH FORM THE CUTTING EDGE OF TOOLS ARE ATTACHED TO STRONG STEEL SHANKS

(Pure copper is used as a solder, and brazing is accomplished in the furnaces. Temperature is maintained at 2050 F.)

(*Courtesy Firth-Sterling Steel Company*)

ACKNOWLEDGMENTS

Acknowledgment is made to Robert H. Leach, vice-president of Handy and Harman, for his kind cooperation, and to that company for facilitating the preparation of this paper. I am also indebted to R. P. Koehring, A. J. Langhammer, and A. MacKenzie for information relating to the respective fields of their interest and activity.

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Refinement of GROUND SURFACES

By HERBERT S. INDGE

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THE PURPOSE of this paper is to describe the methods, processes, and equipment used to produce superfine finishes in the production of metal parts required for accurate machine construction.

The reasons for refining surfaces already ground are manifold. It may be to provide surfaces free from the slight undulations unavoidable in most grinding operations, enabling close measurements to be taken of the physical dimensions; for example, in checking the accuracy of flat work it is customary to employ an optical flat which, when placed upon a lapped or honed surface, will indicate by the interference bands of light the quality of the flatness of the surface. Seldom is a ground surface sufficiently refined to show the slightest result from such a test; a lapped surface will invariably show the interference bands and the error can readily be determined.

Lapping and honing will produce surfaces which will not wear rapidly. Lapped plug and other gages outwear many times those finished by grinding only. Automotive parts are lapped to provide long life, interchangeability, and easy assembly. Pump and compressor parts are lapped to obtain closely fitted joints and minimum clearances.

Ground surfaces have, generally speaking, two defects to be removed by refining processes. The first is surface roughness produced by the grains of the grinding wheel. This varies according to the coarseness of the grit size used, the bonding, means of truing, and other factors. The other defect is that produced by the method or machine used for the grinding operation, and may be in the form of undulations, feed marks, chatters, and general surface irregularities.

To remove such defects it is essential that the process employed in refining does not duplicate the action which produced the errors. Hence, lapping and honing operations use principles entirely different from grinding and polishing.

Surfaces which are to receive superfine finishes must be properly prepared in order to make the process of refinement effective. When all the surface "fuzz" left by the grinding wheel and most of the other surface irregularities have been removed, and the surface is down to base metal, it is extremely difficult to remove more material by lapping; thus, it is necessary to control carefully the quality of the preparatory work.

There are four headings into which this subject may be divided, (1) lapping, (2) honing, (3) superfine grinding, and (4) crankshaft and camshaft finishing.

LAPPING—GENERAL

The term lapping covers a number of methods for producing refined surfaces. Commercially, it refers to lapping with metal laps and loose abrasive, honing with bonded abrasive sticks or wheels, and the polishing of machine parts such as the bearings of crankshafts and camshafts and cam contours, when performed in a mechanical manner, for the purpose of refining a bearing surface.

Primarily, lapping is the ideal superfine finish for hardened steel, and is the ultimate refinement in the production of accurate work. It is essentially an operation to produce accuracy of dimensions, but it is also the process by which surfaces are made flawless within the most exacting requirement.

The finest lapping produces the beautiful "black polish" seen on the faces of gear wheels in good-quality watches and in the best gage work. A black polish is best described by comparing it with a plate-glass mirror. This, when clean and new, will reflect practically all the light received by it, thereby appearing black or invisible. When the surface becomes scratched, the scratches appear as fine white lines. When the scratches are fine enough and sufficiently numerous, the entire surface appears white. Again, when common window glass is silvered, it will reflect a distorted image, due to irregularities in the flatness of the glass. Hence, a black polish is a perfect plane surface with a flawless mirror finish, usually associated with accurately made machine parts.

True lapping is a method of removing metal in small amounts to obtain trueness of form and refinement of the surface simultaneously, and is always performed by the use of abrasive used with laps which, in themselves, have no abrading or cutting action. The comparatively slow rate of stock removal makes it possible to control size accurately and, due to the nature of the abrading action, little or no heat is generated and no glazing of the surface takes place.

The ideal abrasive for lapping, is one which will break down or become finer as the operation of lapping proceeds. Tough or sharp abrasives cut freely but will not produce the luster usually demanded. Two general types of abrasives are available, namely, natural abrasives and manufactured abrasives. Under the first group come emery, corundum, rouge, oxide of chromium, oxide of tin, quartz, diamond dust, and others. In workshop practice, emery and rouge are used when manufactured abrasives are not suitable. Manufactured abrasives include aluminous oxide, silicon carbide, boron carbide, and unfused alumina, the first two of which are the most commonly used.

Fine flour abrasives are necessary and in the finest work the greatest care must be taken to insure that the abrasive chosen is not contaminated by coarser grains of abrasive or other foreign matter; also care must be taken to see that the work and lap are properly protected. It is not advisable to change the abrasive size while lapping, but rather to "wear the abrasive out" as it were, adding only lubricant toward the finish. Compounded abrasives are also sold in powder and paste forms, and very satisfactory results can be obtained by the proper selection of these compounds.

Lapping derived its name from the lapidary whose work was to cut and polish precious stones to enhance their beauty and increase their value. The apparatus employed consists of a slowly rotated horizontal disk, charged with suitable abrasive,

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LAPPING MACHINE WITH TWO-PIECE WORK HOLDER SHOWING SAMPLE OF WORK BEING LAPPED

such as diamond dust for cutting diamonds. The article to be lapped is held in contact with the charged surface and oscillated so that entire working surface of the lap is covered. Proper pressure must be applied between the work and the lap. Too much pressure will strip the abrasive from the face of the lap.

Lapping may be divided into two groups, (1) hand lapping and (2) mechanical lapping. Hand lapping covers external, internal, and flat lapping. It may be called toolroom lapping for it is the method used to lap small quantities of work where more productive arrangements cannot be employed.

HAND LAPPING

External Hand Lapping. To hand-lap a plug gage or similar part, a lap must be prepared, usually and preferably of cast iron. The material of which it is made is important—many mixtures and alloys, products of the modern foundry, are unsuitable for the work. Good results can be obtained from soft close-grained gray-iron castings, free from porosity and other defects. The lap should be made as a split bushing, slightly less in length than the part to be lapped, and of sufficient wall thickness to allow adjustment without undue distortion. The hole must be bored to a good fit on the part, and a smooth straight parallel hole is essential.

The work must be rotated at a moderate rate of speed, and the lap adjusted to a light running fit. The adjustment feature may be in the form of a clamp or dog which may be held in the operator's hand to reciprocate the lap and prevent it from rotating. While the work is rotating, fine abrasive in oil is fed to it through a slot in the lap, which is reciprocated constantly. The operator must develop skill in adjusting the lap to the work by "feel;" this is the technique in hand lapping which differs fundamentally from mechanical lapping.

The operator, in controlling the movement of the lap and making the adjustments required, determines the results obtainable. The best combinations of speed of the work and reciprocation of the lap with suitable abrasive gives a fine crisscross finish which is imperceptible to the naked eye.

Internal Hand Lapping. Internal lapping is performed in the same manner as external hand lapping, with the exception that the lap is chucked and the work held in the operator's hand. The lap is usually made in the form of a split sleeve mounted upon a taper arbor with suitable means of adjusting it to the required size at frequent intervals.

One thing to be remembered in internal, or hole, lapping is that the work has a tendency to become bellmouthed. To overcome this difficulty it is better to have the lap shorter than the length of the hole. Too short a lap will follow the curvature which may be present in the ground hole, and a loose lap will not correct any error but increase the original faults. Great skill must be developed where it is intended to manufacture such parts as small Diesel-engine injector plungers and cylinders.

Flat Lapping. Flat lapping may also be performed as a hand operation. The lap usually employed is in the form of a heavy plate of cast iron, the quality of the iron being soft and close-grained. The surface of the lap must be perfectly flat, and for good work scraping is often necessary to correct errors of machining. After laps have once been used, scraping can no longer be employed, but it must be remembered that the flatness of the lap controls the flatness of the product. A serrated lap is useful for flat lapping.

The operation consists of applying abrasive in a thin paste and rubbing the work on the face of the lap, using figure-eight movements or similar irregular motions to insure even distribution of the wear. Stock removal by this method is directly proportional to the pressure applied. An improvement on this arrangement can be made by adopting the lapidary's principle of rotating the lap.

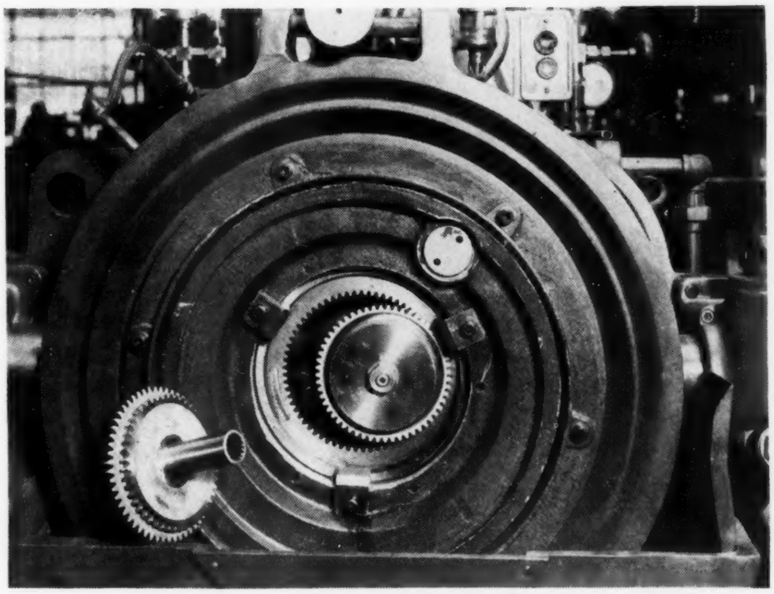
Hardened steel will receive the highest quality of finish by flat lapping, but soft metals can also be lapped, provided suitable abrasives are chosen.

Flat lapping can be either a wet or a dry operation. When performed dry, there are two variations of the method. One method requires a considerable amount of loose abrasive upon the lap, in which case the lap is not serrated. The work is moved so that the grains of abrasive roll between the surfaces, much the way grains of wheat are rolled between millstones. The action produces a reduction of the grain size during the process, which helps to refine the resultant finish. This process is used to lap quartz crystals for radio transmitting sets; in this case, a glass lap is often used. The effect of this class of lapping is to produce a matt finish, bordering on a satin sheen.

The other method of dry lapping depends upon the abrasive's being thoroughly imbedded into the lap. The surface of the lap in this process must be cleaned free from oil, grease, or loose abrasive; in fact, it must appear to be too clean to work, as it were. A cast-iron lap treated in this manner should have a silvery appearance before it is useful for the purpose for which a dry lap is used. The dry lap is used to refine a lapped surface in which crisscross lines are apparent and objectionable. Hardened-steel blocks may be "grained" to appear uniform by this method.

To keep flat laps in good condition for accurate work it is necessary to provide three laps of identical size, numbering them 1, 2, and 3, and lapping one with the other alternately, that is, No. 1 with No. 2, No. 2 with No. 3, No. 1 with No. 3 and so on, thus preventing any convexity or concavity appearing in the lap surface. Surface grinding to refinish flat laps is satisfactory for commercial work.

Lens grinding or lens lapping, both flat and spherical, may come under this heading. In the latter, formed laps are necessary and, generally, the lap is held in the hand for convex lapping, and vice-versa for concave. Water is used as the lubricant for glass lapping, and for rapid stock removal silicon-carbide abrasive is recommended. The work is refined in stages, using successively finer grades of abrasive, and changing from quick sharp-cutting types to the slower finishing mediums. As the lapped surface approaches the finish, the lap must be changed, the final finish being produced on pitch laps with rouge and water.



LAPPING SMALL EXTERNAL SPUR SHOULDER GEAR

(Courtesy of Fellows Gear Shaper Co.)

MECHANICAL LAPPING

Mechanical lapping covers all the methods used in the art, but employs mechanical motions to control the movement of the work relative to the lap or vice-versa, and to adjust automatically the pressure of the lap upon the work. Under this heading external cylindrical, both taper and straight, flat, spherical, and gear lapping are all practical commercial operations. It was the development of mechanical lapping which made it possible to extend the art of lapping into the broad field it covers today.

Forty-two years ago, C. E. Johansson pioneered his famous set of gage blocks by which the standards of interchangeable manufacture are now set. They were not quite so accurate in those days, but he could guarantee any combination of gages, that is, any number of blocks wrung together would still be accurate within 0.00001 in. To make blocks so accurate he depended upon three principles. The first was absolute flatness and parallelism of each block, making it possible to wring one upon the other in almost infinite combination without losing accuracy of dimension. The second was the selection of limits proportionate to the size of the block. The third was stabilization of the steel so that the size of the block was no longer affected by aging. His method of lapping is evidently the origin of the commercial method in use today.

Soon after the World War, C. Harold Wills, building his Wills St. Clair car, demanded wrist pins made to plug-gage accuracy with plug-gage finish. His demand for lapped wrist pins was met by a hand-lapping operation, a most expensive process. At the time the "secrets" of lapping plug gages in multiple in a drill press were made public, and the principle was applied to finishing these particular wrist pins with phenomenal success. It was then that Sydney Player conceived the idea of commercializing lapped wrist pins and pioneered the process under the name "Mirra Finish," later to be accepted as the ultimate in perfection of machine finishes. This Mirra Finish was nearly a perfect black polish and the accuracy was beyond reproach.

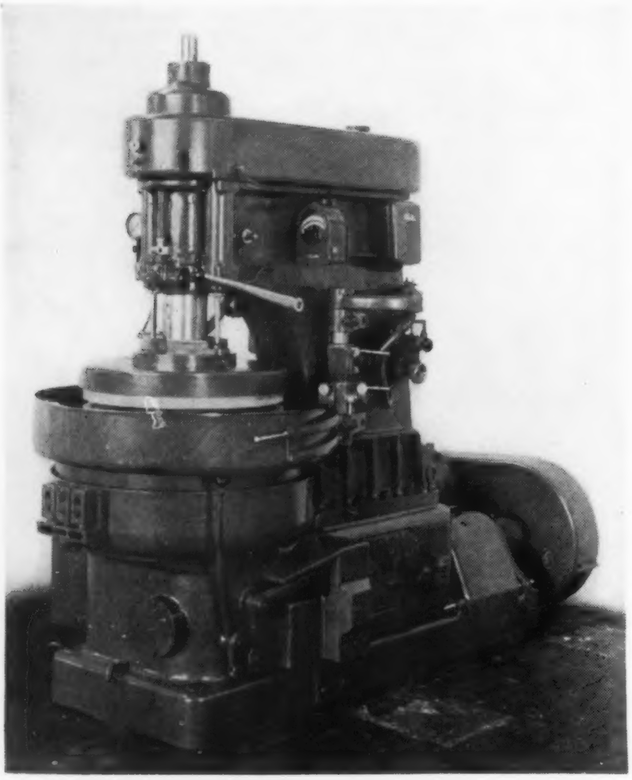
Lapping of wrist pins led to the building of machine tools especially designed to lap, commercially, wrist pins and similar parts in mass production.

The design of the first lapping machine, still satisfactory in many ways, carried a pair of annular cast-iron laps, heavy in section, mounted on vertical spindles and so arranged that while the lower lap rotated, the upper one merely floated, and was raised and lowered by a rack and pinion. The work was carried in a holder called a "spider," having a series of legs protruding from a circular plate. These legs were not quite radial but were tangential to a small circle, such as the spokes of a bicycle wheel, but only in one direction. The center of the work-holder plate was bushed and when loaded was placed in the machine on the face of the lower lap, the center bushing riding on a work-holder drive pin.

In many respects this would describe a drill press set up for a like operation; however, the difference comes in the work-holder drive, which carried a simple crankpin driven at lap speed, an improvement over the drill-press arrangement. This drive pin, which was offset or eccentric was geared so that it rotated slower than the lap and had an odd number of teeth in the gearing. The gear ratio created what is called a "breakup" to insure the work taking an ever-changing path as it rolled over the face of the lap. The arrangement of the work in the machine was similar to a large roller thrust bearing, the laps being the raceways and the work the rollers. The rollers being parallel and lying tangentially on the lap, and being driven by the lower lap rotating while the upper lap provided the pressure, received a rolling, slipping, sliding motion between the surface of the work and the faces of the lap. The work holder, while reciprocated, was not positively driven, but rather was free to rotate much as the cage in a ball or roller bearing. The laps were charged with abrasive and oil and a very fine lapping action was created, which rapidly corrected slight variations in diameter and produced a finish equal to the luster of old silver. By this method 100 to 150 wrist pins per hour could be lapped, removing approximately 0.0005 in. of material, which was sufficient to eliminate all the grinding marks from a commercial grinding operation, and to reduce them to one common diameter.

Flat lapping machines are similar in many ways to the one described for cylindrical work. One type uses the identical arrangement of laps thus described, and differs only in the work drive mechanism. Another type, built by Major Hoke for the Bureau of Standards during the World War, employs stationary laps with the work holder moving between. In flat lapping, while the multiple principle is still employed, it is essential that the work be made to change its position continuously with regard to the lap, and to cover at some time in its path all the working surface of the lap.

When hand lapping flat surfaces, a toolmaker uses many varied strokes, such as the figure eight, in order to break up the



FLAT AND CYLINDRICAL LAPPING OR HONING MACHINE

path and distribute the wear equally over the entire surface of the lap. With this knowledge, the designers of flat-lapping machines incorporated such movements, making it possible to lap flat work continuously with very little unequal lap wear.

The basic features of mechanically lapping flat work involve holding the work so that it is seldom rigid, but rather free to be lapped on both sides simultaneously, without the strains being released first from one side and then from the other as in grinding. There is no magnetic chuck to cause distortion or to deflect pieces of thin section, and no heat is generated during the lapping process.

Taper Lapping. It is not practical to lap tapers by hand; however, a modification of a standard cylindrical lapping machine makes it possible to lap tapers equally as well as common cylindrical parts. The machine is arranged as previously described for cylindrical work, but the face of the upper annular lap is changed so that it is conical. It will be approximately the complement of the included angle of the cone or taper of the work. When the work is arranged in the same tangential manner as is used for wrist pins or the like, the lower edge of each part will then lie upon the flat surface of the lower lap. The lower lap must then be given an oscillating or reciprocatory motion in order to secure the desired rolling, slipping, sliding motion previously mentioned.

Spherical Lapping. Arrangements for spherical lapping use spherically shaped laps. This is the fundamental principle, for without such shaped laps there can be no area in contact to create a lapping action. One principle is to rotate the work and the lap on separate spindles, the axes of which are inclined one toward the other.

Gear Lapping. This is one operation not generally preceded by grinding; nevertheless, it is a refining operation that may well be considered a part of this program.

Gear lapping is usually confined to hardened-steel gears which have been refined prior to the heat-treatment so that only the most minute errors remain to be eliminated. The favored method of preparing the work is by shaving the teeth. Other means, such as burnishing, may introduce local strains which result in distortion during the hardening process. It is recommended the greatest care be given to the machining operations, the steel analysis and the heat-treatment of all gears to receive a lapping operation, so that only the least amount of metal remains to be removed in the final process, remembering that in this as in practically all lapping and honing operations it is not a stock-removing proposition but one of refinement only.

There are many methods of lapping gears, nearly all of which rely upon the principle of meshing the gear to be lapped with other gears, and, while rotating, reciprocating, or otherwise causing the teeth to be in frictional contact, a compound of abrasive and lubricant is pumped or fed to the moving parts to be "ground up" by the gears. This is literally what happens, because the abrasive and the vehicle finally become virtually ineffective and must be regularly replaced to maintain a constant cutting action.

To follow the best practice in gear lapping it is essential to treat each type of tooth with the shape of lap and relative motion between work and lap which will insure as much cutting action as possible, with the least error being created in the tooth form of the lap. It is recommended by one manufacturer that spur gears be lapped with a ring or internal gear lap, while he recommends helical gears be lapped by similar helical gears. Another advises lapping helical gears with spur laps and vice-versa, using special tooth forms for the laps.

Spur gears require a lapping motion difficult to obtain by simple reciprocation of the work relative to the lap, if the latter be an external gear or group of external gears, although it is claimed that by a combined rotary and reciprocatory motion, together with a varying center distance between the work and the lap, a surface scrubbing or crisscross action can be obtained. The most convenient way is by meshing the work with a single internal gear lap, having a few more teeth than the work, and providing a rotating and reciprocatory motion to the work, while the lap rotates upon its own axis, held at correct center distance from the work. The lap is given a braking action but is otherwise free to rotate when propelled by the work, while the latter may be driven in either direction alternately. The compound of abrasive and oil, kept agitated, should be fed continuously.

Reference to the proper relationship between speeds of rotation and the stroke, or reciprocation, is of great importance. It is well known that certain steels, given specific treatments, will either swell or contract the tooth, sometimes causing the effect of fattening the tooth either at the top or near the root. By adjusting the relative rotary and reciprocatory speeds the fatness may be removed as required, for it is found that by increasing the work speed and reducing the reciprocation, the tooth laps more above the pitch line, and, conversely, if the speed or rotation is decreased and the reciprocation increased, the lapping is concentrated nearer the root or below the pitch line.

Another way to lap spur gears employs external gear laps in groups of three, cut with special-shaped helical teeth which mesh with the spur teeth. The axes of the work and the laps are inclined so that the teeth will mesh; thus, when they rotate together there is considerable slippage between the gear-teeth faces without the need of lateral reciprocation.

Helical gears may be lapped by mating with a group of laps which are also helical gears. In this arrangement the work is mounted so that it may be rotated alternately in either direction and the laps arranged in planetary form around the work on

fixed center distances, free to rotate, but provided with brake mechanisms similar to the arrangement described for spur-gear lapping.

Internal gears may be lapped in ways similar to those described, but by reversing the setup; in this case, the lap is rotated and reciprocated, while the work is free to rotate, but receiving a braking action.

An earlier method of gear lapping employed a simple reciprocating and indexing mechanism to support the work. In this arrangement a ring-gear lap with exactly the same number of teeth as the gear to be lapped is provided, and the gear is meshed with the lap, reciprocated a few times with pressure applied to one flank, then indexed a tooth and the process continued until the work has made a full turn. The operation is then repeated with the work indexed in the reverse direction, thus applying the pressure to the other flank. In this type of lapping the plan is to distribute the error in the entire gear uniformly and in like manner distribute the lap wear, so that it may be used until the teeth actually break off.

In gear lapping it is best to pump a mixture of abrasive and oil over the work during the lapping operation. The abrasive for this class of work may be silicon carbide in fine sizes such as No. 180, No. 280, XF, or other standard mediums. The material must be renewed more or less frequently, because both the abrasive and the vehicle appear to "wear out."

Gear-tooth honing with bonded abrasives is in the experimental stage and will probably eliminate some of the difficulties encountered with the use of loose abrasive.

HONING

The early use of the term "honing" was probably confined to the barber who "honed" his razor after grinding, to refine the edge. The earliest hones were natural stones of fine soft grade. Later the abrasive industry developed manufactured products of great uniformity—a feature lacking in the natural variety.

Honing is now a process of refining surfaces of metal in a way similar to lapping, but using a slightly different technique. Honing uses bonded abrasive as a cutting medium; in other words, if laps were made of bonded abrasive, lapping would become a honing operation. This is the fundamental difference between the earlier art and this modern development of the process. One valuable feature in honing is the absence of loose abrasive and the comparative cleanliness of the operation as compared with lapping.

The best-known example of commercial honing is cylinder honing. Cylinder hones of many designs for internal honing are on the market, all similar in construction, varying only in features of adjustment, methods of supporting the stones, and minor structural differences. The sticks or hones proper are usually long and narrow, presenting a comparatively small area to the work.

Internal honing heads carry a multiple of sticks except in the case of heads for very small holes, in which case it is necessary to curtail the number and use but one. Some heads are provided with noncutting sticks to steady the action, and all work on the principle that they must be rotated and reciprocated at relatively slow rates of speed.

Honing flat work may be performed in machines constructed on similar lines to those designed for flat lapping. The major difference is in the fact that abrasive wheels, used in the place of annular cast-iron laps, need to be trued when mounted, and as often as required afterward, to eliminate any effects of wear, glazing of the surface, or other similar conditions.

For flat lapping and flat honing it is essential that the working surface of the laps or wheels, whatever they may be called, should be absolutely flat. A concave or convex condition, however slight, is detrimental to successful results.

Flat wheels will produce flat work and to this end carefully aligned truing devices are part of the machines designed for the work. To enable both wheels to be trued without disturbance and to better the action of lubricating the face of the wheels, the typical vertical lapping machine used for this work carries two live spindles, and the opposed annular faces of the wheels run in opposite directions at moderately slow speeds. A truing device, which passes a diamond across the face of both wheels simultaneously, will make both wheels perfectly flat and true.

The work holders used are similar in every respect to those of machines using cast-iron laps, and the mechanism which drives them is also similar.

Machines of this type have been most successful in producing flat surfaces on any material without fear of "charging," that is to say imbedding the abrasive grains, however slight, in the surface of the work.

Cast-iron piston rings, soft steel gears, pump rotors, and bronze thrust washers may be safely refined to the smoothness and accuracy comparable with the finest lapping. Hardened-steel parts, such as the roller tooth used in modern automobile steering gears, thrust washers, parts for oil burners, rayon pumps, refrigerators, and bearing races are typical examples of work successfully finished by honing.

For flat honing, wheels of silicon carbide in special grain of fine sizes and with a vitrified bond are satisfactory. The coolant is kerosene or similar light oil.

External cylindrical honing may be performed in machines

CLOSE-UP VIEW OF LAPPING ARMS OF CRANKSHAFT LAPPING MACHINE

similar to that described for flat honing. A different selection of wheels is necessary, and a lubricant of soap and water is satisfactory. It has been found that 0.0002 in. is ample stock for operations such as wrist pins.

Honing internal tapers, such as taper roller-bearing cups, calls for special machinery. The principle differs from regular internal honing in which the hole itself is the guiding factor for the honing head, for in this case, as in lapping taper rollers, it is necessary to provide means to control the taper. A conventional design supports the work horizontally, rotating it at a moderate rate of speed, and providing a sliding member parallel with the angular face of the conical surface. The sliding member carries a suitable stone or honing stick reciprocated at a rate of speed that produces a microscopically crosshatched surface. The speed of rotation and the speed of reciprocation must be regulated to suit the size of the work.

The principle of reciprocating honing sticks may be applied in other ways, both for internal and external work, but difficulty may be experienced in finding abrasive sticks suitable for some materials, especially soft steel or nonferrous metals. There is a distinct tendency for small chips of metal to become imbedded in the working surface of the stone. When this occurs the particle of imbedded metal scores the surface being honed.

SUPERFINE GRINDING

The refinement of surfaces produced by commercial grinding is accomplished by grinding with one or more finer grinding wheels. This method produces a surface finish suitable for rolling-mill rolls and work of similar nature. By successively grinding with finer wheels, each grind is intended to remove less than the depth of grain cut of the previous grind; thus it is possible to obtain a reflective mirror finish, but not the perfect black polish previously mentioned. There will remain, in spite of all precautions, a series of fine circumferential lines, polished to a high degree and barely visible to the naked eye. This finish must not be confused with lapped or honed surfaces, because both the latter have a distinct crosshatched finish unobtainable by common grinding methods.

Changing wheel speeds can also be resorted to for finer finishes which are required for rolls, wheel spindles, and similar products.

Typical wheels and sequence of operation follows: Rough, No. 50 J silicon carbide; second, No. 150 K-5 silicon carbide shellac; third, No. 320 K-5 silicon carbide shellac; final, No. 500 I-9 silicon carbide shellac.

The centerless grinder also produces superfine finishes, especially when arranged with wide wheels, and the wheel speeds reduced below normal. The finish from the centerless type will have the typical circumferential lines.

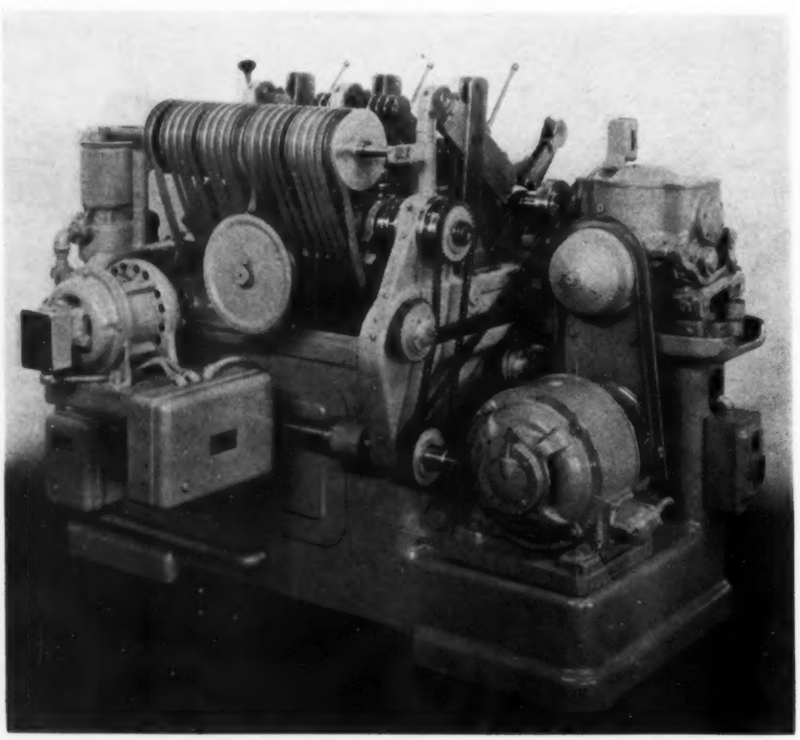
CRANKSHAFT AND CAMSHAFT FINISHING

To refine the bearing surfaces and cam contours of automobile camshafts and crankshafts, special machines have been devised to correct the errors and refine the surface without making it an expensive operation.

Machines have been made carrying split cast-iron laps, to envelop all the bearings of a crankshaft simultaneously, much the way as the toolmaker hand-laps plug gages. The results were very fair as far as quality of surface and accuracy were concerned, but owing to the difficulties of cleaning the surfaces after lapping, the method was discarded. Later, abrasive sticks were inserted in the laps in an attempt to eliminate this difficulty, but it was not easy to obtain sticks which would cut or hone without picking up small particles of metal. Recently, better honing sticks have made this process show new promise, especially when accompanied with a high rate of reciprocation.

The accepted method of finishing crankshafts and camshafts is by the use of coated abrasive paper or cloth, employing the same technique of rotating and reciprocating the work within closed shoes or laps.

Camshafts are in a category similar to the crankshafts. Very fine results are obtained by the use of coated abrasive cloth in a machine especially designed for the work. A duplicate camshaft rotated in unison with the work, controls the movement of a group of individual slide members. In addition to reciprocating the work, a high-speed reciprocatory movement is given to the group of slide members carrying the abrasive elements. This is an excellent camshaft finishing operation for it effectively removes all grinding marks.



CAMSHAFT LAPPING MACHINE SHOWING DRIVE OF DUPLICATE CAMSHAFT

CONCLUSIONS

Refinement of ground surfaces made necessary by the demands of industry for improved products must be planned by the designing engineers.

Surface finishes are built up, finer abrasives being used for each subsequent operation.

Lapping and honing operations permit production of refined surfaces at high production rates as well as at extremely moderate cost.

Accuracy of physical dimensions is dependent upon refined surfaces. Fine limits demand fine surfaces.

FATIGUE *and* CORROSION FATIGUE *of* STEELS

By BLAINE B. WESCOTT

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MODERN engineering problems require for their solution detailed and accurate knowledge of the properties of materials, and the degree of success in satisfying the ever-increasing demands of current industrial progress is determined largely by the adequacy of such knowledge. In this era of high-speed transportation and capacity production of durable goods, it is essential that the engineer have at his disposal a fund of thorough information relative to the behavior of engineering materials under static, repeated, and impact stresses. This paper is a brief review of present knowledge regarding some aspects of the behavior of steel under repeated stresses, a phenomenon universally referred to as fatigue, and it is the author's hope that this knowledge may be applied to the development of more durable equipment for the production of crude oil. The term "fatigue" is not accurately descriptive since it suggests that the metal becomes tired and, if given an opportunity to rest, would recover.

Steel, however, does not recover from damage by repeated stresses and the implication from the term that the effects are only temporary is erroneous. Just as the elastic limit, or in ductile metals the yield point, is a criterion for resistance to static stresses so is the fatigue limit or endurance limit of steel a measure of its ability to resist repeated stresses. By the term endurance limit is meant that unit stress which may be applied to a given steel for an indefinitely large number of cycles without producing rupture. The stresses may be variable both in nature and magnitude over an infinitely broad range of conditions, thereby making it essential that conditions of service be defined when reference is made to endurance limit. Unless qualified in this manner the endurance limit commonly means the greatest unit stress which will not cause failure after an indefinite number of applications of alternating stresses, i.e., when the negative and positive stresses are numerically equal.

HISTORICAL

A brief review of the history of fatigue will provide an interesting background for the subsequent discussion of some of the phases of this interesting subject. As early as 1837 Hodgkinson in England, as a result of experiments, suggested that the repetition of any stress, however small, would permanently deform the member subjected to that stress (1, 3).[1] Several years afterward a commission was appointed to inquire into the suitability of iron for the construction of railway bridges, and as a result of an investigation under the supervision of this committee it was realized, apparently for the first time, that if a material failed under repetitions of a stress not great enough to cause failure on the first application, two possible explanations existed: First, that the ultimate tensile strength deteriorated with time or, second, failure was due to the mere repetition of the applied stress. This led to some experiments with cast iron under repeated impact as a result of which it was shown that failure could result from the repetitions of stress less than the ultimate strength and was not caused by deterioration of the cast iron with time. One of the earliest reports on the effect of repeated stress is that of Fairbairn in 1864 who, working for the Board of Trade, tested a wrought-iron girder 22 ft long and 16 in. deep, made up of plates and angles. He concluded that working stresses up to 11,000 lb per sq in. were safe. The first comprehensive series of repeated-stress tests was that carried out by Wöhler in repeated torsion, bending, and direct stress. He spent 12 years on his experiments and the results were published over a considerable period beginning in 1860. Wöhler was the first investigator to pay strict attention to the actual magnitude of the applied stress and for that reason it is of interest to review his conclusions as summarized by Moore and Kommers (3): (*a*) Wrought iron and steel will rupture at a unit stress not only less than the ultimate static strength of the material, but even less than the elastic limit, if the stress is repeated a sufficient number of times. (*b*) Within certain limits the range of stress rather than the maximum stress determines the number of cycles before rupture. (*c*) For a given minimum or maximum unit stress an increase of range of stress decreases the cycles necessary for rupture. (*d*) For a given minimum or maximum unit stress there appears to be a limiting range of stress which may be applied indefinitely without producing rupture. (*e*) As the maximum applied unit stress increases, this limiting range of stress decreases. The limiting stress values arrived at by Wöhler are given in Table 1.

TABLE 1 ENDURANCE LIMITS DETERMINED BY WÖHLER FOR BARS SUBJECTED TO BENDING OR TENSION COMPRESSION

Material	Stress, lb per sq in. Maximum	Stress, lb per sq in. Minimum	Ratio of endurance limit to tensile strength
Wrought iron	+17,100	−17,100	0.36
	+35,300	0	0.74
	+47,100	+25,700	0.99
Cast steel	+30,000	−30,000	0.29
	+51,400	0	0.49
	+85,600	+37,400	0.82

It would be equally absorbing to review in detail the early constructive work of Bauschinger, Ewing, Rosenhain, Humfrey, Bairstow, Goodman, Johnson, Haigh, and others; but it would be at the expense of the limited space available for discussion of the more recent contributions of R. R. Moore, Jasper, Kommers, H. F. Moore, Gough, McAdam, and many other able present-day investigators.

DETERMINATION OF ENDURANCE LIMIT

While there are numerous types in use, the rotating-beam fatigue-testing machine developed by R. R. Moore is the most common and will serve to illustrate the methods by which en-

[1] Numbers in parentheses refer to Bibliography on page 827.

Contributed by the Petroleum Division and presented at the Mid-Continent Section Meeting held at Tulsa, Okla., November 16, 1937, of The American Society of Mechanical Engineers.

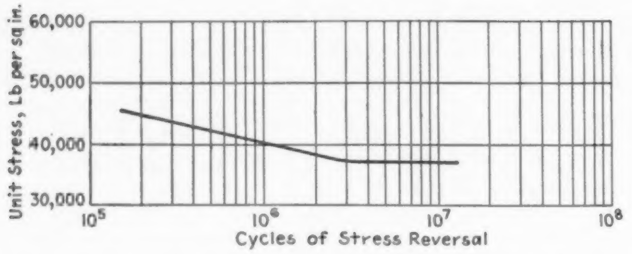


FIG. 1 A TYPICAL *S-N* DIAGRAM FOR MEDIUM-CARBON STEEL

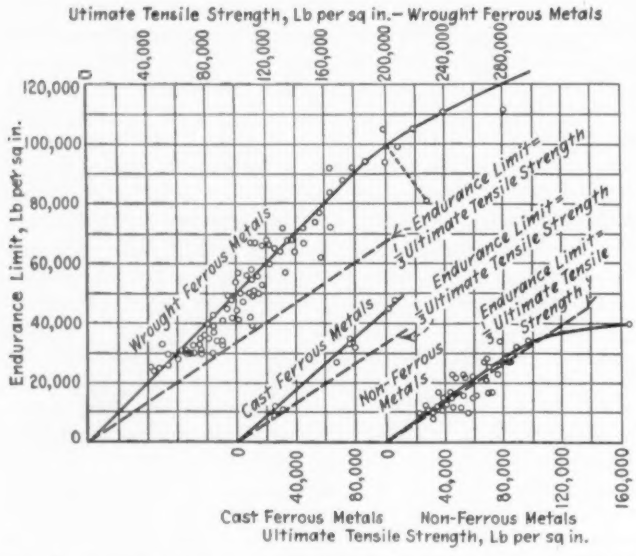


FIG. 2 CORRELATION OF ENDURANCE LIMIT AND TENSILE STRENGTH

durance limits of steel are determined. The load is applied in a transverse direction to the rotating specimen which functions as a beam supported at the ends and loaded uniformly over the center section. The outer fibers of the specimen are under maximum tension on the top and maximum compression on the bottom; the stress along the neutral axis is zero. The stress on the specimen is calculated from the beam formula

$$S = Mc/I \qquad [1]$$

where S = stress, lb per sq in.; $M = Pa$ = bending moment at the critical section of the specimen, in-lb; P = load on the specimen, lb; a = distance from the point of loading to the critical section of the specimen, in.; and I = moment of inertia of the specimen = $0.049d^4$, where d = diameter of the specimen at the critical section, in.

It is convenient to determine fatigue strength by the use of diagrams in which the computed stress values are plotted on semilogarithmic paper as ordinates and cylces of stress to failure as abscissas. Plotted in this manner the stress-cycle diagrams, or *S-N* curves as they are commonly called, become horizontal, as nearly as can be determined, at the endurance limit which requires 500,000 cycles for very hard steels, 5,000,000 for soft steels, 10,000,000 for cast steel and cast iron, and 50,000,000 for aluminum and copper-nickel alloys. A typical *S-N* diagram for medium-carbon steel is shown in Fig. 1. It is clear from the foregoing outline that fatigue testing is both expensive and time-consuming and there has, consequently, been considerable effort devoted to the development of shorter test methods. These have been entirely unsuccessful up to this time and there is no satisfactory substitute for the method of endurance testing which has been briefly outlined. It has been possible to shorten the tests somewhat by increasing the rate of stress application up to 10,000 cycles per min without materially altering the results but if the speed of application is further increased, higher endurance limits are found.

CORRELATION OF FATIGUE LIMIT WITH TENSILE STRENGTH

The endurance limit of a ferrous alloy is thus seen to be a fairly specific property when conditions of testing are defined, but it cannot be definitely correlated with any of the common static physical properties except the tensile strength. This relationship is shown diagrammatically in Fig. 2 from numerous tests on irons and steels of widely varying compositions and heat-treatments (3). For no ferrous alloy plotted did the endurance limit fall below one third of the tensile strength. The relationship was not as definite for the nonferrous alloys. In the absence of test data, the endurance limit for reversed flexure of wrought ferrous alloys may be estimated as 45 per cent, and for cast ferrous alloys as 40 per cent, of the ultimate tensile strength not exceeding 200,000 lb per sq in. The relationship is variable for higher-strength steels. In a general manner the ratio of endurance limit to tensile strength or the endurance ratio, as it is commonly called, is greater for low- and medium-carbon steels heat-treated to give maximum ductility than for higher-carbon steels heat-treated to give high strengths, but in spite of this generality there is no correlation apparent between endurance limit and ductility.

EFFECT OF NATURE OF STRESSES ON FATIGUE LIMIT

The nature of the stresses has a pronounced influence upon the endurance limit. In Table 2 are listed the results obtained from steels tested in reversed flexure and reversed axial stressing.

TABLE 2 COMPARISON OF ENDURANCE LIMITS UNDER TRANSVERSE AND AXIAL LOADING

Material	Endurance limit, lb per sq in. — Reversed transverse stresses	Endurance limit, lb per sq in. — Reversed axial stresses	Ratio of axial to transverse endurance limits	Reference[a]
Armco iron	25200	20000	0.79	..
3.5 per cent nickel wrought iron	42600	39500	0.93	23
0.35 per cent C-1.25 per cent Mn steel	48900	45800	0.94	23
Nickel steel	26000	26000	1.00	..
Nickel steel	34000	30000	0.88	..
0.15 per cent carbon steel, annealed	25500	24500	0.96	4
0.37 per cent carbon steel, annealed	30000	33000	1.10	4
0.68 per cent Cr-2.93 per cent Ni steel	55000	56200	1.02	4
0.84 per cent Cr-3.33 per cent Ni steel	61500	58200	0.95	4
Forged manganese bronze	16000	17500	1.09	4
Copper, annealed	11300	11000	0.97	4
Nickel, annealed	38000	41500	1.09	4
Monel metal, annealed	40000	40000	1.00	4

[a] Numbers in this column refer to the Bibliography at the end of the paper.

The lowest ratio of fatigue limit for axial stressing to transverse stressing reported was 0.7. Irwin (4) found the endurance limits had practically the same values when extreme care was taken to insure true axial loading. This condition seldom exists in actual service so it is probable that the average ratio is approximately 0.85. A comparison of fatigue limits under reversed bending stresses with those under reversed torsional stresses is given in Table 3 (3). From these data it is evident

TABLE 3 FATIGUE STRENGTH UNDER REVERSED FLEXURAL AND REVERSED TORSIONAL STRESSES

Material	Endurance limit, lb per sq in. Reversed torsion	Reversed flexure	Ratio of endurance limits in torsion to flexure	Reference[a]
Armco, annealed	12700	26000	0.49	8
0.24 per cent Carbon steel, as rolled	14000	25500	0.55	26
0.38 per cent Carbon steel:				
Normalized	17500	32000	0.55	26
Oil-quenched and drawn	21500	33500	0.64	26
0.52 per cent Carbon steel, normalized	22000	42000	0.52	10
0.93 per cent Carbon steel:				
Annealed	16300	30500	0.53	8
Troostitic	52000	98000	0.53	8
3.5 per cent Nickel steel:				
Annealed	29000	54000	0.54	10
Oil-quenched and drawn	36000	64000	0.56	10
Chrome-nickel:				
Annealed	25000	49000	0.51	10
Oil-quenched and drawn	33000	66000	0.50	10

[a] Numbers in this column refer to the Bibliography at the end of the paper.

that the endurance limit of steel under reversed torsional stresses is only about one half as great as the corresponding value in reversed bending.

The most common fatigue tests are those in which the stress is completely reversed. This condition is not so common, however, in service applications, and there has been consider-

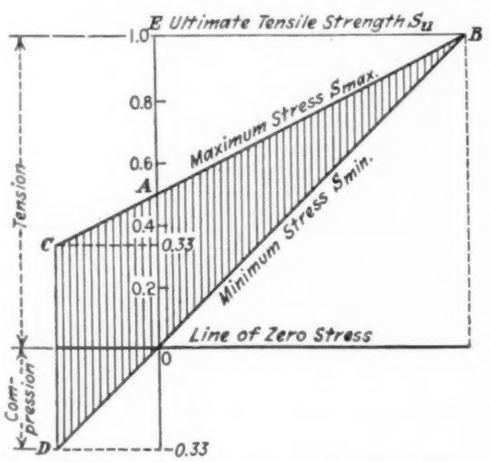


FIG. 3 GOODMAN DIAGRAM FOR RANGE OF STRESS

able attention given to the theoretical calculation of safe working ranges of stress. Range of stress is the algebraic difference between stress in a cycle to which the specimen or working part is subjected. The Goodman (5) diagram probably has received the most general recognition of all formulas proposed for the calculation of safe ranges of stress. This diagram, shown in Fig. 3, is based on the dynamic theory of suddenly applied loads, according to which the maximum instantaneous stress produced is twice that which would be produced if the same load were gradually applied. As explained by Moore and Kommers (3), the ordinate of the line *EB* represents the tensile strength; the horizontal line through 0 is the line of zero stress, tensile stress being plotted above the line and compressive stresses below it. The minimum stresses are plotted along a 45-deg line *DOB*. According to the theory, the minimum or dead-load stress plus twice the live-load stress equals the tensile strength. The maximum applied stress should, therefore, fall on the line *CAB* such that the point *A* is one half the tensile strength. It is clear from the diagram that when the minimum stress is zero then the maximum safe stress is one half the tensile strength, and when the stress is reversed as at *CD* then the tension and compression stress could not exceed one third the tensile strength. The diagram implies that as the maximum stress is increased the minimum stress must also be increased algebraically if failure is not to occur. Gough (2), after applying test results to the diagram, concluded that it did not always indicate safe ranges of stress. Moore and Kommers (3) conclude that the diagram is conservative for ferrous alloys subjected to completely reversed stresses. The latter investigators suggest the following formula as an alternative to the Goodman diagram

$$\frac{S_{max}}{S_{-1}} = \frac{3}{2 - Y} \qquad [2]$$

where S_{max} = maximum unit stress in a cycle, S_{-1} = endurance limit for reversed flexure, and Y = range ratio for a cycle. A more exact expression for the effect of range of stress must await further experimental data, particularly in the regions of compressive stresses alone.

NATURE OF FAILURE BY FATIGUE

The mechanism of failure by repeated stresses should be examined before consideration of the more specific aspects of fatigue. Gough (2) states in this regard that it must be admitted that no completely acceptable comprehensive theory of fatigue has yet been advanced. The truth of this statement is fully realized by those who must specify types of steel for service under repeated stresses, especially if the problem is further complicated by the presence of corrosion. It should not be necessary any longer to dispel the old belief that metals crystallize and become brittle under repeated stresses and that fatigue failures are consequently brittle failures. It has been proved definitely, by ample experimental evidence, that there is no essential difference in the nature of failure under static loading from failure in fatigue. Metallographic studies of steel under repeated stresses have shown that rupture is always preceded by the phenomenon of slip. Fig. 4 shows slip bands in a piece of Armco iron which was stressed above the endurance limit. From the regular arrangement of the bands it is evident that movement has taken place along definite crystallographic planes within the metal grains.

Speaking on this subject in the Eighth Marburg Lecture, Gough (6) stated that the mechanism of slip is equivalent, geometrically, to one of shearing, and that the slip direction always coincides with a crystallographic direction of maximum linear atomic density. From an extended investigation of fatigue of single crystals and specimens consisting of only two or three crystals, Gough concluded that the essential characteristics of deformation and failure of polycrystalline materials are substantially the same as observed for monocrystalline specimens. Considering, then, the fatigue characteristics of a single crystal of a ductile metal it has been established adequately that fatigue failure is inseparably associated with failure of elasticity by the process of slip. Fatigue failure must, therefore, be viewed as a sequel to slip; and, although the exact

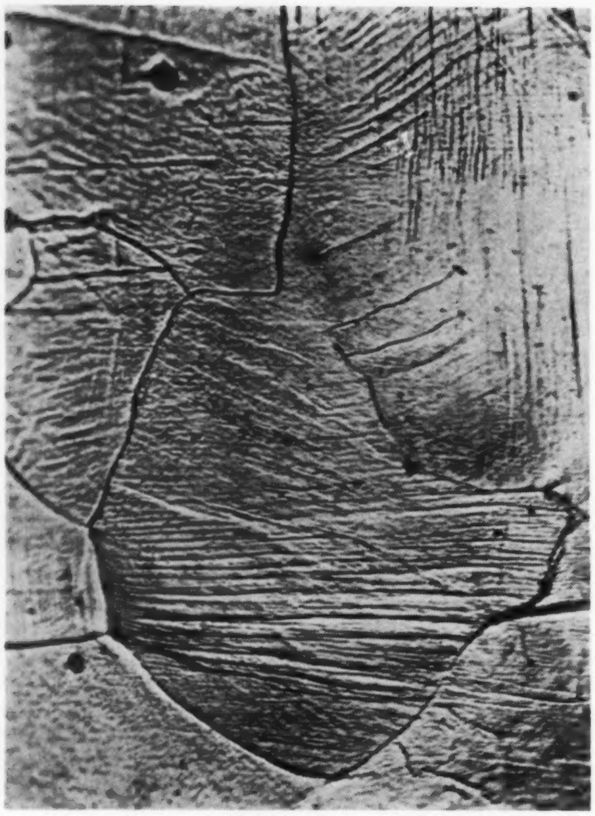


FIG. 4 SLIP BANDS IN ARMCO IRON AFTER FATIGUE FAILURE

nature of slip is somewhat obscure, a logical conception of the mechanism of subsequent failure by fatigue can be evolved in the light of observed phenomena.

X-ray analysis has shown that slip is not merely relative movement between adjacent parts of the crystal but that the structure becomes fragmented into component parts of differing orientation. This action, as is well known, is accompanied by strain hardening but there is no certainty that strain hardening is a direct consequence of fragmentation. Continued application of stress causes the slip and strain hardening to proceed, not uniformly, but locally both with respect to individual grains and with respect to sections within the grains at the junctions of the crystallites formed by fragmentation or crystal breakup. The state of strain upon atomic bonds at these boundaries is intense and the limiting value of some is ultimately exceeded as the process of cold working by repeated stressing continues so that rupture is produced in the atomic lattice structure. When the stress exceeds the fatigue limit the rupture of atomic bonds becomes a cumulative effect, with the result that the discontinuities of structure develop through the stage of submicroscopic cracks into that of visible cracks which spread, under continued stressing, in the well-known progressive manner of fatigue failure. According to this theory a fatigue crack has its inception within a grain and is propagated in an intracrystalline manner rather than in an intercrystalline manner. An interesting side light of this basic work being carried out at the National Physical Laboratory is Gough's suggestion that crystallites make up the grain boundaries in metal and that change of orientation between grains is effected by a number of very small crystallites of slightly differing orientation, the structure of each being appreciably free from lattice distortion but having strained or ruptured atomic bonds at the junctions. This conception, it appears, is more in harmony with the known facts of the crystalline nature of metals than the older amorphous theory of Rosenhain (7). The discussion of the important rôle of slip in failure by fatigue must be terminated prematurely by the observations that while slip is most readily developed at high stresses, slip bands have also been observed after a large number of cycles of stresses considerably below the endurance limit. Therefore, visible slip does not necessarily connote impending fatigue failure. Conversely, an absence of visible slip is not a positive indication of freedom from damage.

EFFECTS OF PROCESSING TREATMENTS UPON FATIGUE LIMIT

The effects of some of the more common fabricating processes on the endurance limit of steels have been investigated extensively. The outstanding effect of cold work on steel is to raise its elastic strength in the direction of rolling. Commercial cold-drawing and cold-rolling processes increase markedly the elastic strength of steel, and also the tensile strength, but to a lesser degree. The fatigue strength seems to be increased to about the same degree as the tensile strength. From what has been said earlier regarding the correlation between endurance limit and tensile strength, it is obvious that heat-treatment may greatly influence the fatigue limit of a steel. Fig. 5, taken from the results of an extended investigation of fatigue at the University of Illinois (8), illustrates this action in a typical manner. In the pearlitic condition the 0.43 per cent carbon steel had an endurance limit of 30,500 lb per sq in. This was increased 84 per cent by a heat-treatment which imparted a sorbitic structure, and 221 per cent when the resulting structure was troostitic. Moore and Jasper (9) found that the outside shell of high-carbon steel which results from carburizing is very effective in increasing the endurance limit. For example, a 0.20 per cent carbon steel had its endurance limit increased 67 per cent by case hardening followed by heat-treatment, while the corresponding increase for Armco iron amounted to 120 per cent.

The effect of understressing on the fatigue limit is variable but, in general, subjecting the steel to a large number of cycles at stresses slightly less than the fatigue limit increases this property. Some of the results of Moore and Jasper (10) are shown in Fig. 6. All specimens in these tests had been subjected to 100,000,000 cycles of stress without failure, and they were then retested at stresses increased by small increments above the original endurance limit until failure resulted. Those steels in the upper group show a marked increase in fatigue strength while those in the lower group were not appreciably benefited. The broad generalization might be permitted that

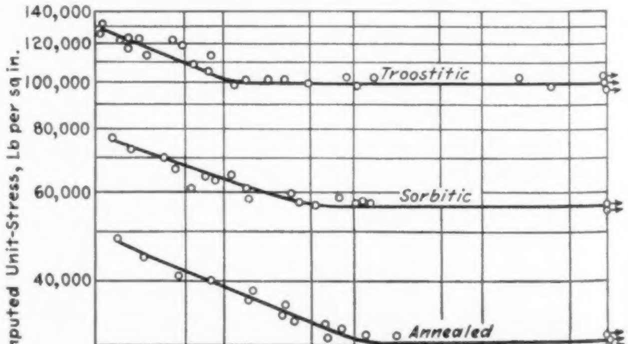


FIG. 5 EFFECT OF HEAT TREATMENT ON ENDURANCE LIMIT

those steels which have had their strength materially increased by heat-treatment apparently do not have their strength increased much by understressing which, after all, is one method of cold hardening.

Steel parts are frequently subjected to more or less overstressing, and behavior under these conditions is often a criterion of the suitability for application to such service. Stress beyond the endurance limit eventually starts a minute fatigue crack, and both experience and experiment indicate that once a fatigue crack is started it will spread under subsequent cycles of stress below the original endurance limit of the metal. In general, ductile metals are superior to brittle metals in this respect, but ductility is not the only factor involved. Certain ductile alloy steels seem to be highly susceptible to damage by occasional overstress. Apparently, the ability of the steel to absorb the energy of the cycles of overstress is, in some cases, as important as the ability to withstand high unit stress. The usual testing technique must be expanded to determine the susceptibility of a steel to damage from overstress. Subsequent to the determination of the usual *S-N* graph, specimens may be subjected to a range of repetitions of overstress and then tested at the fatigue limit to ascertain whether or not damage resulted. Probably the most useful method of summarizing the effects of overstress is that shown in Fig. 7 and used by French (11) in discussing this phase of fatigue in the Campbell Memorial Lecture of 1933. The solid circles are placed to indicate the conditions of overstress; adjacent arrows which point downward indicate damage as determined in subsequent tests at the original fatigue limit, horizontal arrows indicate no change, and arrows pointing upward designate improvement in fatigue

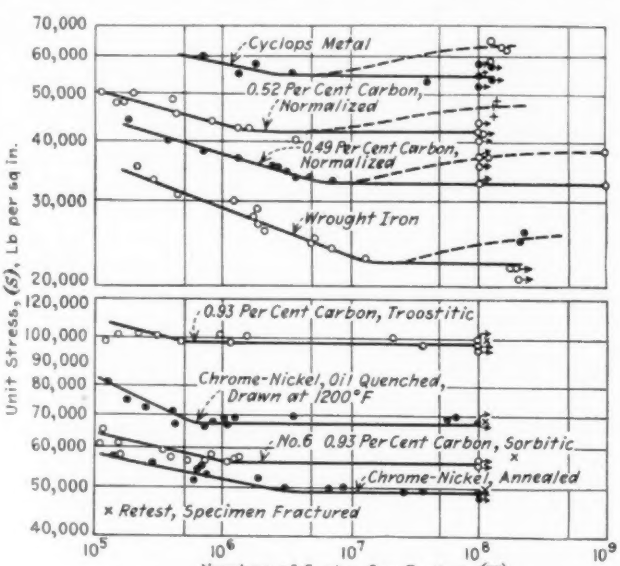


FIG. 6 EFFECT OF UNDERSTRESSING ON ENDURANCE LIMIT

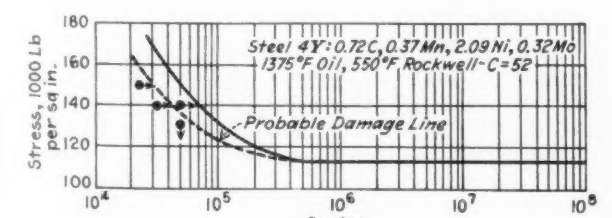


FIG. 7 EFFECT OF OVERSTRESS UPON THE LIFE OF QUENCHED AND TEMPERED NICKEL-MOLYBDENUM STEEL

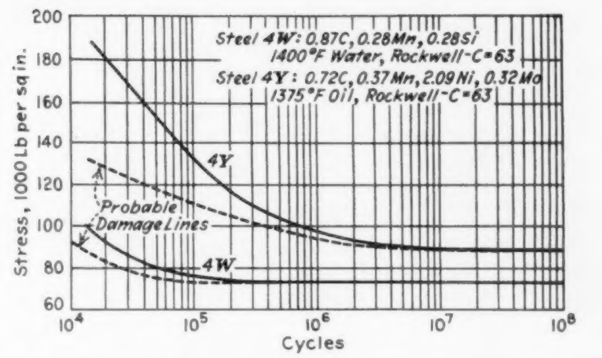


FIG. 8 EFFECT OF OVERSTRESS UPON WATER-QUENCHED HIGH-CARBON STEEL, AND OIL-QUENCHED HIGH-CARBON NICKEL-MOLYBDENUM STEEL

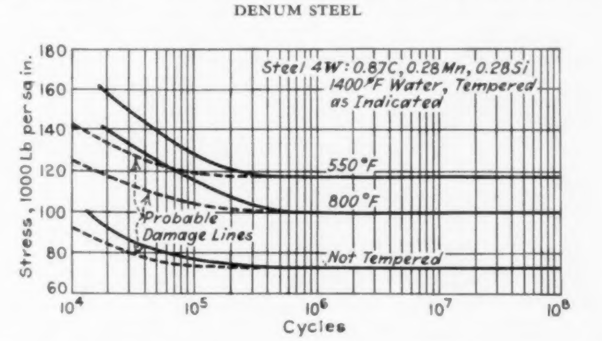


FIG. 9 EFFECTS OF TEMPERING ON THE FATIGUE RESISTANCE OF WATER-QUENCHED HIGH-CARBON STEEL

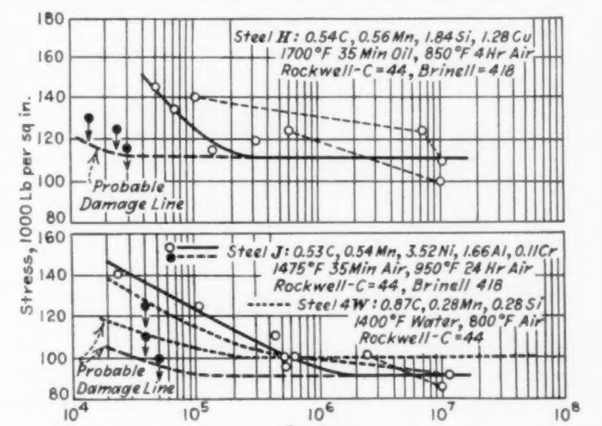


FIG. 10 *S-N* CURVES AND PROBABLE DAMAGE LINES FOR AGE-HARDENED COPPER-SILICON, NICKEL-ALUMINUM, AND HIGH-CARBON STEELS OF SIMILAR HARDNESSES

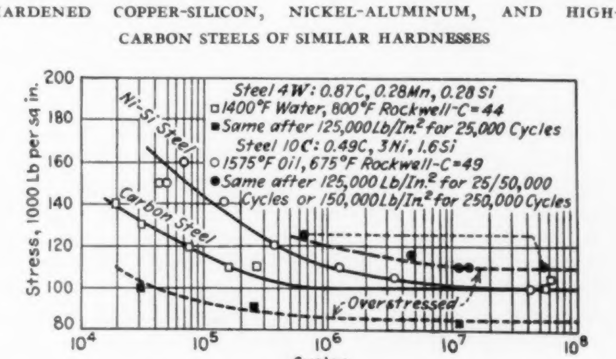


FIG. 11 EFFECT OF OVERSTRESSING ON THE FATIGUE RESISTANCE OF HIGH-CARBON AND NICKEL-SILICON STEELS

TABLE 4 FATIGUE PROPERTIES OF MATERIALS

Materials	Fatigue limit, lb per sq in.		Fatigue ratio, fatigue limit to tensile strength		Notch resistance, fatigue limit (notched) ÷ fatigue limit (std.)	Relative stress at 25000 cycles: Stress ÷ fatigue limit		Relative stress at 25000 cycles: Damage stress ÷ fatigue limit	
	Std.	Notched	Std.	Notched		Std.	Notched	Std.	Notched
Cast iron	20000	17000	0.45	0.38	0.85	1.60	1.40	1.50	1.10
Molybdenum cast iron	28000	20000	0.55	0.40	0.72	1.50	1.47	1.04	1.10
Cast pearlitic malleable	44000	31000	0.56	0.50	0.71	1.52	1.78	1.21	1.00
Malleable iron	29000	19000	0.54	0.35	0.66	1.55	1.58	1.34	1.47
Copper malleable	32000	21000	0.56	0.37	0.66	1.41	1.72	1.00	1.00
Copper malleable, hardened	33000	20000	0.51	0.31	0.61	1.51	1.90	1.18	1.75
Copper cast steel	49000	28000	0.56	0.32	0.57	1.53	1.82	1.14	1.07
Copper cast steel, hardened	58000	28000	0.55	0.26	0.48	1.73	1.89	1.21	1.57
Wrought iron *A*	30500	20000	0.65	0.43	0.66	1.57	1.70	1.03	1.47
Wrought iron *AT*	28000	19000	0.60	0.41	0.68	1.46	1.69	1.20	1.32
Wrought iron *B*	25 80	19000	0.53	0.40	0.76	1.80	1.84	1.42	1.71
Wrought iron *BT*	25000	18000	0.67	0.48	0.72	1.64	1.67	1.20	1.61
Ingot iron	29000	19000	0.65	0.42	0.66	1.45	1.71	1.00	1.53
0.35 per cent carbon steel	35500	20500	0.52	0.30	0.58	1.41	1.85	1.01	1.17
S.A.E. No. 4130	65000	...	0.52	...	...	1.40	...	1.12	...
18 per cent Cr-8 per cent Ni stainless steel	33000	36000	0.38	0.41	1.09	1.12	1.22	1.09	1.11

resistance. A line may be drawn in the *S-N* graph to indicate the boundary at which damage is liable to occur. The area below the damage line defines safe stress-cycle conditions and when this area is large the metal may be said to have a good resistance to overstress, while when small, the steel is readily damaged by overstress.

French (11) also presented data on a group of steels heat-treated to comparatively high hardnesses. Some of the more interesting results he reported are pertinent to this review. In Fig. 8 are given the *S-N* curves for a 0.87 per cent carbon steel and a 0.75 per cent nickel-molybdenum steel, the former water-quenched and the latter oil-quenched to the same hardness. The oil-quenched alloy steel had a higher fatigue limit and also better resistance to overstress than the water-quenched carbon steel. The inferiority in fatigue resistance of the carbon steel is related, in considerable degree, to the magnitude of internal residual stress as shown in Fig. 9, which gives the *S-N* curves for the same steel after tempering at 550 F and 800 F, respectively. French (11) attributes the improved fatigue resistance partly to stress relief and partly to structural changes comprised of the tempering of the martensite and decomposition of retained austenite into alpha iron and carbide.

However, few data are available on the fatigue properties of age-hardened steels. Fig. 10 summarizes fatigue tests of a silicon-copper steel, a nickel-aluminum steel, and a carbon steel all heat-treated to the same hardness, the first two by suitable aging treatments and the last by water-quenching and tempering. These data indicate that high fatigue limits may be obtained in some alloys capable of giving high hardness on aging, but that these same alloys are very readily damaged by overstress, although after damage occurs there is an appreciable lag before rupture. Both the age-hardening steels were strengthened by understressing.

Only one steel, a nickel-silicon steel containing 0.49 per cent carbon, 3.00 per cent nickel, and 1.60 per cent silicon, showed strengthening by overstressing. The *S-N* curves of this steel and a carbon spring steel at spring temper are compared in Fig. 11. Both steels were overstressed to 125 per cent of their identical fatigue limits and the endurance limits determined as on the original steels. Conditions of overstress which damaged the carbon steel improved the fatigue strength of the nickel-silicon steel so that the overstressed nickel-silicon steel had a fatigue limit about 30 per cent higher than that of the overstressed carbon steel. The nickel-silicon steel had a high susceptibility to temper brittleness (ratio = 5), that is, the Izod impact values of samples water-quenched from the tempering temperature of 1200 F were five times those obtained on furnace-cooled samples. This led French (11) to suggest that the two effects may be related if temper brittleness be regarded as one type of aging, that is, the decay of a supersaturated solid solution. The decay of supersaturated solutions involves precipitation of microscopic or submicroscopic particles, a process which can often be initiated by cold work. Consequently, decay conceivably may be initiated also by the slip resulting from overstressing, and the accompanying deposition of finely dispersed particles in the slip planes might obstruct further slip and thereby exert a strengthening action.

NOTCH SENSITIVITY AND STRAIN HARDENING

Notch sensitivity is an important characteristic of steels subjected to fatigue since their behavior in the presence of highly localized stresses at points of abrupt change in section such as keyways, fillets, oil grooves, or at the roots of threads or the base of corrosion pits is often the difference between a satisfactory and an unfortunate selection. This phase of fatigue was recently investigated quite extensively at Battelle Memorial Institute with interesting results. The notch sensitivity was determined for sharp 90-deg notches cut in standard rotating-beam specimens while damage in both the unnotched and notched conditions were determined for 25,000 cycles of overstress. Some of the results reported by Russell and Welcker (12) are given in Table 4. Referring to this table, the notch resistance is expressed as the ratio of the notched fatigue limit to the ordinary fatigue limit, and the reciprocal of this ratio is the stress-concentration factor as commonly employed. In overstress, the stress at 25,000 cycles relative to the fatigue limit for similar specimens provides the basis for comparison. The cast irons and wrought irons are relatively insensitive to notches, which is undoubtedly one reason for better performance in some types of fatigue service than would be expected. In general, it has been noted that materials with low tensile strengths are least damaged by stress concentration, possibly because they are usually highly ductile and are readily work-hardened. Both cast iron and wrought iron have a multitude of internal notches or stress raisers, the first by reason of the graphite and the second because of the slag, which are inherent components of the respective structures. In the presence of these conditions of high internal localized stresses when under load it may be imagined readily that the effect of deliberately produced notches on the surface is not as great as would be found for materials relatively freer from internal stress concentrators.

Another common manner in which stress concentration is

induced in metal parts is through pressed or shrunk fits. Peterson and Wahl (13) report that the endurance limit of such a fitted member is reduced to approximately one half that of the shaft material without stress concentration. Horger and Maulbetsch (14), investigating the improvement resulting from (*a*) relief grooves in the end faces of the pressed-on members, (*b*) providing raised seats or pads on the axle at the press-fitted portion, and (*c*) the variation of material and heat-treatment, state that about 30 per cent increased strength is the maximum obtainable. Surface rolling, however, is capable of effecting much greater improvement and is now being used in many industrial applications. Some of the results obtained by Horger and Maulbetsch with S.A.E. 1045 steel normalized at 1620 F and drawn at 1115 F are given in Table 5. Thus, surface rolling

TABLE 5 EFFECT OF SURFACE ROLLING ON THE ENDURANCE LIMIT OF PRESS-FITTED ASSEMBLIES

Press fit, in.	Roll pressure, lb	Load carried through pressed-on member	Endurance limit, lb per sq in.	Per cent
0.000	0	No	34400	100
0.001	0	No	15000	44
0.001	600	No	33000	96
0.001	1200	No	34000	99
0.001	0	Yes	12000	35
0.001	600	Yes	24000	70
0.001	1200	Yes	28000	81

or, what is probably a more descriptive term, strain hardening of the surface, increased the endurance strength from 2 to $2^1/_3$ times that of the conventional press-fit assembly.

Some interesting and more recent investigations are related to the notch sensitivity and strain-hardening propensities of steels in that measurement is made of a characteristic termed "work sensitivity" by Case (15). In their reaction to cold work, steels exhibit a much greater degree of nonuniformity in impact toughness than in any other physical property. For instance, consider the effect, reported by Case, of a reduction of area of 2.2 per cent by cold drawing on two heats of low-carbon (0.2 per cent) steel of practically identical chemical composition and hot-rolled physical properties. Izod impact tests on one heat gave a value of 86 ft-lb before cold drawing and only 8 ft-lb after cold drawing, while the tests from the other heat gave values of 64 ft-lb and 67 ft-lb, respectively. The alteration in other physical properties of the two steels as a result of the cold-drawing operation was of the same order of magnitude. Apparently then, the impact test is a sensitive means of measuring the reaction of steel to cold work. In order to shorten the testing procedure, a special test specimen has been devised. It consists of a tapered round bar 10 in. long in the tapered section, which section is 0.450 in. in diameter at one end and 0.475 in. at the other end. This test piece is drawn through a die having a diameter of 0.450 in., thereby producing gradually increasing increments of cold work from zero at one end to 10.3 per cent reduction of area at the other end. The cold-drawn bar is then notched with the standard Izod notches at 1.1-in. intervals, thus furnishing eight tests representing degrees of cold work varying by increments of 1.2 per cent reduction of area. The Izod values are then plotted as ordinates against the per cent reduction of area by cold drawing as abscissas. When the slope of this curve is sharp and the general level low, the steel is termed sensitive, and when the slope is gradual and the level high, the steel is termed insensitive. It has been found that reaction to this test is an inherent property of an entire heat of steel and that, generally speaking, inherently fine-grained steels are less sensitive than inherently coarse-grained steels. As an example, Fig. 12 shows work-

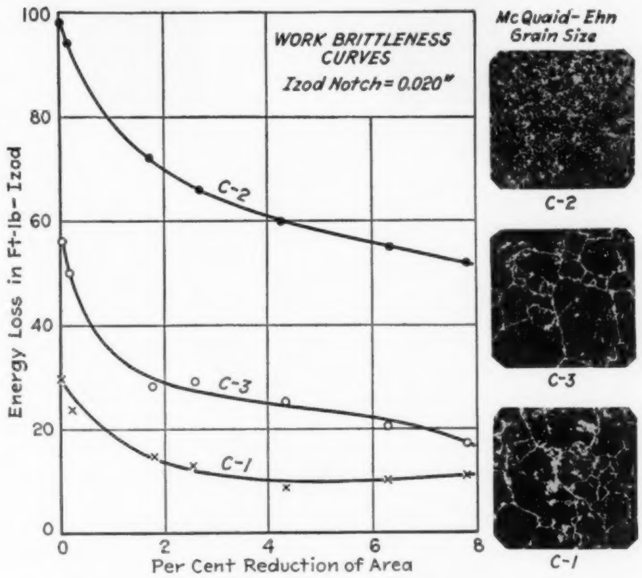


FIG. 12 WORK-BRITTLENESS CURVES AND MCQUAID-EHN GRAIN SIZES FOR THREE HEATS OF CARBON-MANGANESE STEEL OF THE SAME COMPOSITION

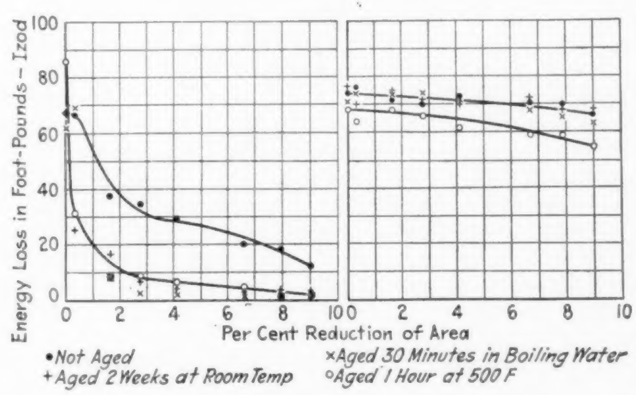


FIG. 13 WORK-BRITTLENESS AGING TESTS ON TWO HEATS OF STRUCTURAL STEEL OF THE SAME COMPOSITION

sensitivity curves for three heats of steel of nearly identical chemical compositions and containing approximately 0.60 per cent carbon and 1.15 per cent manganese. The McQuaid-Ehn grain size at a magnification of 100 diameters is also shown.

The work-sensitivity test has also been found useful to measure the aging characteristics of steels. In Fig. 13 the work-brittleness aging curves for the two low-carbon steels previously mentioned are shown; on the left is the sensitive steel and on the right is the comparatively insensitive steel. The sensitive steel is also a rapidly aging steel. When similar curves on a single steel for different aging conditions are prepared they show not only the magnitude of strain-aging effects, but also indicate the degree of cold work at which these effects are most intense.

DAMPING CAPACITY AND FATIGUE

Case (16) has corroborated the evidence obtained from work-sensitivity tests by damping tests. Space does not permit a discussion of damping or the method of making damping tests; therefore, only a brief reference to this interesting subject is possible. Föppl (17) defines damping capacity as the amount of work dissipated into heat by a unit volume of the material

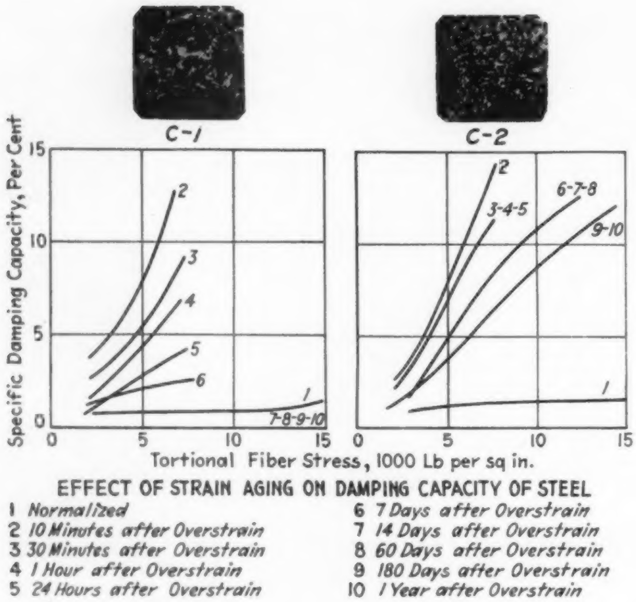


FIG. 14 DAMPING-CAPACITY AGING CURVES FOR INHERENTLY FINE-GRAINED AND INHERENTLY COARSE-GRAINED CARBON-MANGANESE STEELS OF THE SAME COMPOSITION

during a completely reversed cycle of stress. The test specimen acts as a spring of an elastic oscillating system which vibrates in its own natural frequency without external impulses or losses of energy. Case was unable to correlate damping capacity definitely with inherent grain size, composition, heat-treatment, static and dynamic properties; variations in these have comparatively minor effects. He did find, however, that cold working invariably raises the damping capacity of steel to levels that cannot be approached by any other treatment, and that the damping test is a particularly sensitive indicator of aging after cold working. The curves in Fig. 14 depict the progress of aging after cold working the test specimens, by twisting to a permanent set of 90 deg of two of the 0.60 per cent carbon, 1.15 per cent manganese steels mentioned just previously. The steel on the left, an inherently coarse-grained steel, shows a rapid decline in damping capacity to the original value after work hardening. The steel on the right, an inherently fine-grained steel, shows only a slight loss in damping capacity after long aging.

The reason for reference to damping capacity in this discussion lies in its possible relationship to fatigue strength. It was at first thought (18) that measurement of the damping capacity might be a rapid method for the determination of the fatigue strength of a steel, but this still remains to be established. Brophy (19) recently investigated the notch sensitivity of steels in fatigue with relation to grain size and damping capacity. Briefly stated in a general way, he found that: (*a*) Inherently fine-grained steels had lower damping capacity than inherently coarse-grained steels. (*b*) The effect of grain size as developed by heat-treatment was to increase the damping capacity as the grain size increased. This effect was of greater magnitude than the effect traceable to inherent grain size. (*c*) Coarse-grained steels have lower notch sensitivity. (*d*) Inherently fine-grained steels in the heat-treated condition are damaged less than coarse-grained steels by overstresses.

Brophy speculated that increasing the grain size of any steel develops greater plasticity, as indicated by increased damping capacity, and localized stresses are quickly lessened in intensity by local yielding; at the same time, the metal is work-hardened more because of its greater plasticity. In some austenitic steels it is possible, by enlarging the grain size, to produce a higher fatigue limit for notched specimens than that for unnotched specimens of the same steel in a fine-grained condition. The rate of failure depends, according to Brophy (19), fundamentally upon the damping capacity. A steel having a low damping capacity shows great resistance to the start of a crack, but once started, complete failure is sudden because of its high notch sensitivity. Conversely, a steel of high damping capacity starts a crack at relatively few cycles of stress, but because of its low notch sensitivity, failure progresses slowly. Thus, there are indications that a relationship may exist between damping capacity and damage from overstresses.

CORROSION FATIGUE

No discussion of fatigue would be complete without some consideration being given to the effects on steel of simultaneous corrosion and repeated stresses which, through common usage, is termed "corrosion fatigue." Since damage to steel by corrosion is variable, depending upon the time of exposure to and the nature of the corroding medium, the definition of the corrosion-fatigue limit of a steel must take these factors into account. Thus, the corrosion-fatigue limit is the greatest unit stress which may be applied to the metal under given conditions of stress, rate of stress application, temperature, and corrosion

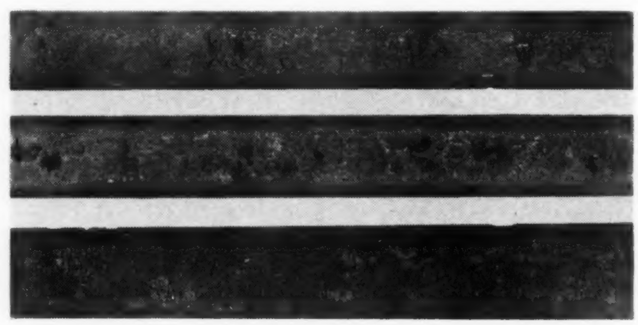


FIG. 15 ACTION OF CORROSION FATIGUE ON OIL-WELL SUCKER RODS

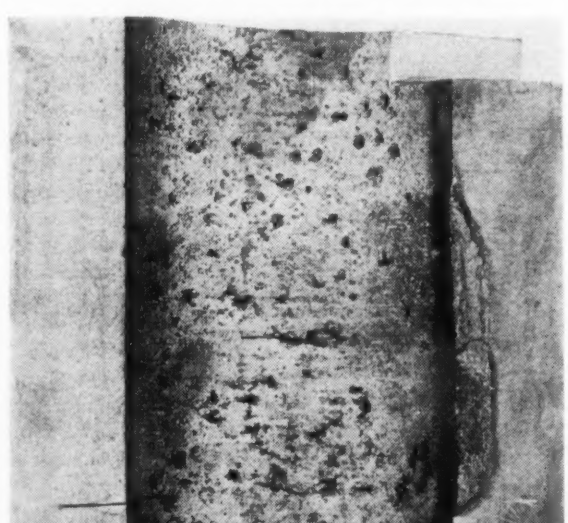


FIG. 16 ACTION OF CORROSION FATIGUE ON A WATER-COOLED STAINLESS-STEEL PLUNGER OF A HOT-OIL CHARGING PUMP

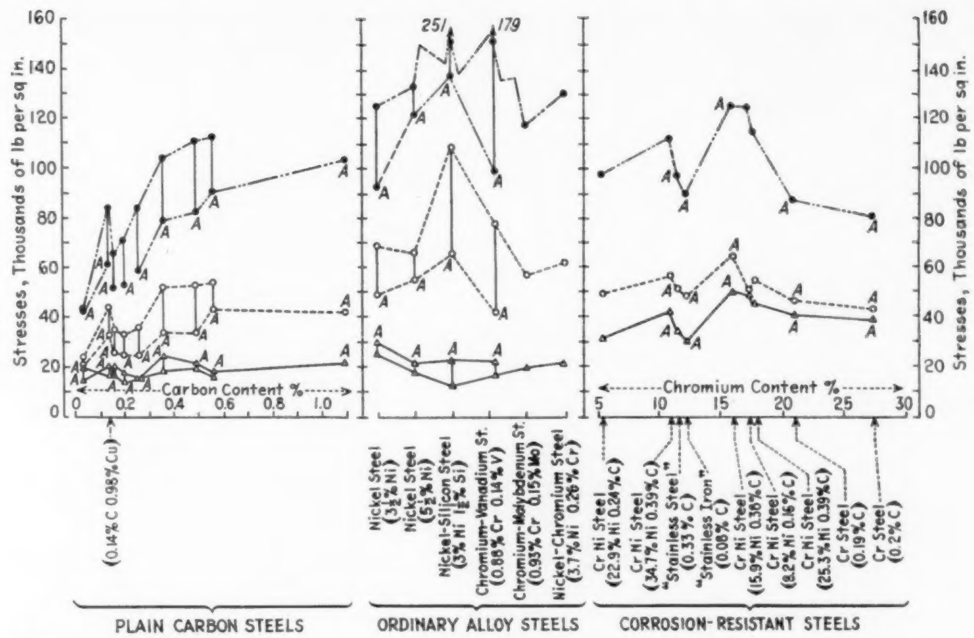


FIG. 18 INFLUENCE OF COMPOSITION AND HEAT TREATMENT ON CORROSION-FATIGUE LIMITS OF STEELS

without causing it to fail in a given number of cycles of stress. From this definition it is clear that, unless corrosion is arrested, the *S-N* graph of a steel in corrosion fatigue never becomes asymptotic to the abscissa or zero-stress line.

First reference to corrosion fatigue is generally credited to Haigh (20) who reported in 1917, fatigue results for brasses in contact with corrosive agents. However, credit is due in a large measure to McAdam (21) for much of the present extensive knowledge of corrosion fatigue as a result of his systematic and comprehensive investigations which have been published in the interval since 1926.

Typical examples of failures from corrosion fatigue are shown in Figs. 15, 16, and 17. Fig. 15 shows failures in oil-well sucker rods, Fig. 16 shows a failure in a stainless-steel plunger of a hot-oil charging pump, and Fig. 17 shows failures in superheater tubes. As is most frequently the case, there is visible evidence of damage to the materials.

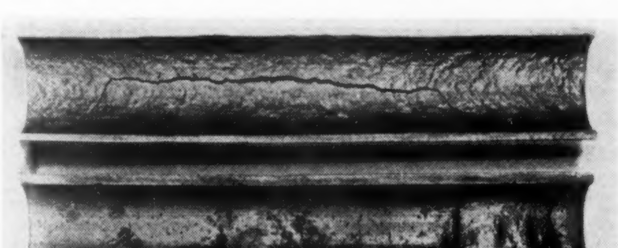


FIG. 17 FAILURE OF SUPERHEATER TUBES FROM CORROSION FATIGUE

There is not sufficient space to discuss the influence of the numerous factors such as stress range, time, number of cycles, temperature, and corrosivity of environment. Those interested in these details are referred to the excellent review by Gough (22), which comprised the Eleventh Autumn Lecture of the Institute of Metals. As an example of typical results, Fig. 18 is taken from the published data of McAdam (21). All tests were made under identical conditions, the specimens being exposed to the corrosive action of a stream of fresh water in the presence of air while being stressed at 1450 cycles per min for 20,000,000 cycles in rotating-beam testing machines. Included are plain-carbon, medium-alloy, and corrosion-resistant steels in various conditions of heat-treatment. The following generalizations are evident from these data: (*a*) There is no relation between corrosion endurance limit and tensile strength. (*b*) For plain-carbon steels there is no definite effect attributable to the carbon content. (*c*) Medium-alloy steels have slightly higher corrosion-fatigue limits than plain-carbon steels, but the benefit is not in proportion to their higher cost. (*d*) Internal stress resulting from heat-treatment has a deleterious effect on the corrosion-fatigue limits of plain-carbon and medium-alloy steels. (*e*) Corrosion-resistant steels have higher corrosion-fatigue limits than carbon or medium-alloy steels. (*f*) Chromium is more effective than nickel for increasing the corrosion-fatigue limits of corrosion-resistant steels.

Results of corrosion-fatigue tests in the absence of air are given in Table 6 (23). The tests were made on rotating-beam machines at 1750 cycles per min for 10,000,000 cycles of stress. The water was a brine containing 67,940 ppm of sodium chloride. This brine was saturated with hydrogen sulphide for the sulphide corrosion-fatigue tests. The damage ratios are taken as the ratio of corrosion-fatigue limit to fatigue limit, and sulphide-corrosion-fatigue limit to fatigue limit, respectively. These data lead to the following generalizations which apply,

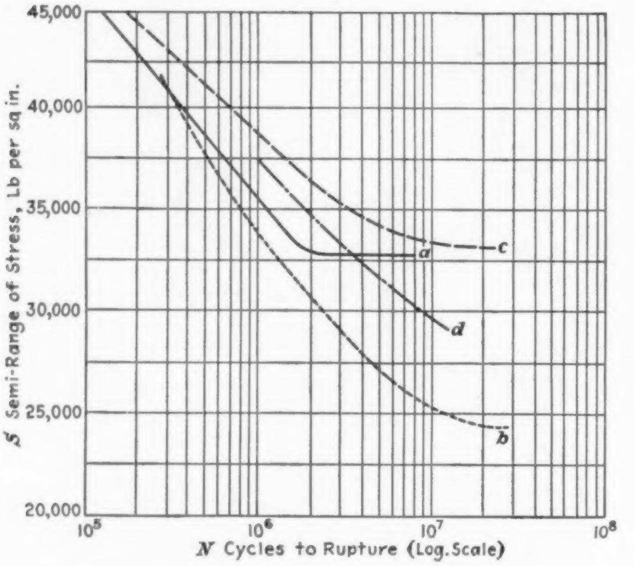


FIG. 19 EFFECTS OF ACCELERATORS AND INHIBITORS ON CORROSION-FATIGUE LIMIT OF 0.35 PER CENT CARBON STEEL

(Curve *a* shows the air endurance of the metal; curve *b* shows the corrosion endurance of the metal in water containing 25 ppm each of sodium chloride and sodium sulphate; curve *c* shows the effect of adding 200 ppm of sodium dichromate to this water as an inhibitor; and curve *d* shows the corrosion fatigue of the metal in the inhibited water when a narrow band of paint was located at the center of the specimen so as to produce oxygen-concentration cells.)

of course, only to the conditions of test as described and particularly to the absence of air: (*a*) Damage from corrosion fatigue in salt water is less than in fresh water in the presence of air. (*b*) Some medium-alloy steels are damaged much less by corrosion fatigue than carbon steels. (*c*) Low-carbon steels are damaged proportionately less by corrosion fatigue than steels with medium- or high-carbon contents. (*d*) Steels in the heat-treated condition suffer greater damage than when in the normalized, annealed, or hot-rolled conditions. (*e*) Chromium is the most effective alloying element for increasing the corrosion-fatigue strength in the absence of hydrogen sulphide, and nickel is the most effective alloying element for increasing the corrosion-fatigue strength in the presence of hydrogen sulphide.

The important rôle played by oxygen, corrosion inhibitors, and corrosion accelerators is illustrated in a striking manner by some results of Speller, McCorkle, and Mumma (24) shown in Fig. 19. The conditions of test were similar to McAdam's; the material was a 0.35 per cent carbon steel in the normalized condition. Curve *a* is the air endurance curve; *b* is the corrosion endurance curve of the metal in water containing 25 ppm each of sodium chloride and sodium sulphate; curve *c* shows the effect of adding 200 ppm of sodium dichromate to this water as an inhibitor; and curve *d* shows the corrosion fatigue of the metal in the inhibited water when a narrow band of paint was located at the center of the specimens so as to produce oxygen-concentration cells, i.e., an anodic section at the edge of the paint band. Not only did the inhibitor prevent lowering of the fatigue limit but it moved the curve bodily to the right, due to the cooling effect of the water. Two important facts are brought out by these tests which are of general application in corrosion fatigue: First, the damage to steel by corrosion fatigue is largely dependent upon the rate of corrosion of the steel in the corroding environment, and, second, the effect of repeated stresses upon the rate of corrosion is of minor importance.

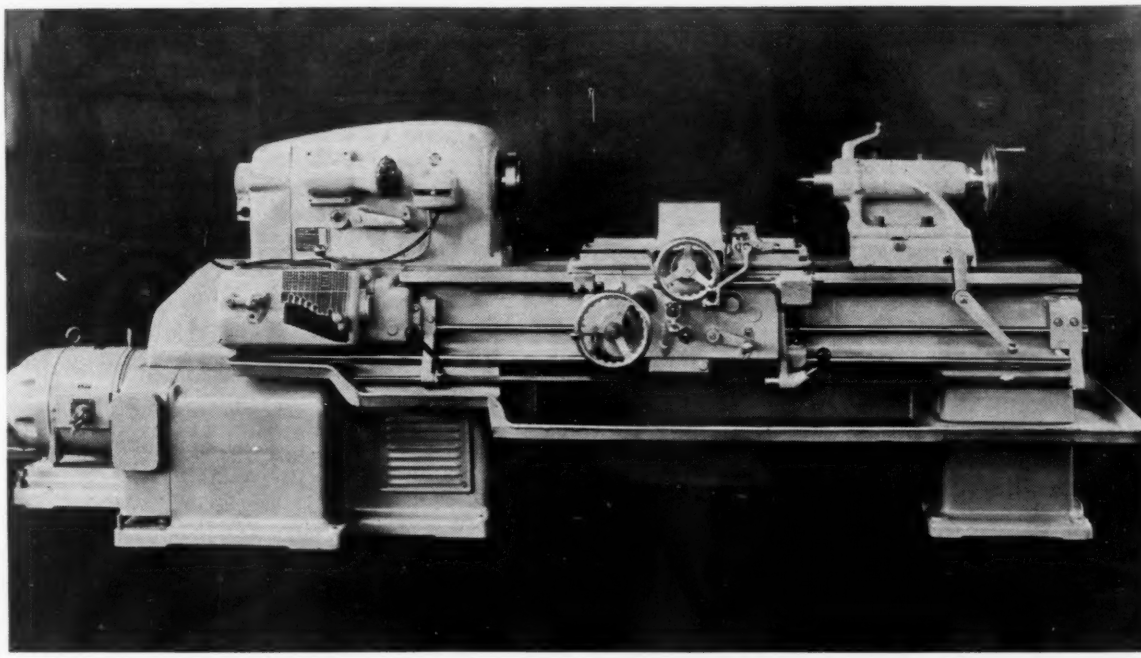
It is now possible to visualize the probable mechanism of failure by corrosion fatigue for which McAdam (21) is largely responsible. The history of failure can be divided into two periods. During the first stage of corrosion fatigue, damage is done to the steel, resulting in a condition (by pitting, crack formation, wastage, etc.) such that if the corrosive environment were removed altogether, fracture due to cyclic stresses would result ultimately by the process of a spreading crack or cracks. Thus, what will be termed the "second stage" is essentially a fatigue stage in which failure proceeds according to the general laws of fatigue, the most important characteristic feature of which is the propagation under the applied cyclic stresses of a crack by stress-concentration effects and the magnitude of which is controlled primarily by the shape of the crack and the physical properties of the material. This is a very satisfactory theory since it so closely parallels the conception of failure by ordinary fatigue. Indeed, it is analogous if corrosion be considered simply as one way to cause localized concentrated stresses by damage to the surface. In other words, notches are formed by chemical action rather than by mechanical means. Consequently, existing knowledge of notch sensitivity, strain hardening, and other features of fatigue can be applied with advantage to problems of corrosion fatigue.

It should be recognized, however, that the rate of corrosion of a metal in a given corrosive medium is probably not the same when it is being subjected to cyclic stresses as when it is unstressed or under static stress. Evans (25) and others have

(*Continued on page 828*)

TABLE 6 CORROSION-FATIGUE LIMITS OF STEELS IN SALT WATER IN THE ABSENCE OF AIR

		Fatigue limit, lb per sq in.				Damage ratio	
Material	Tensile strength, lb per sq in.	Air	Corrosion	Sulphide corrosion	Fatigue ratio	Corrosion	Sulphide corrosion
S.A.E. 1035	88500	40600	24600	10600	0.46	0.61	0.26
S.A.E. 1050	93400	31600	19900	10900	0.34	0.63	0.34
S.A.E. 1050, water-quenched and drawn	130100	60100	25400	13900	0.47	0.42	0.23
S.A.E. 2315	79700	51900	31600	23900	0.65	0.61	0.46
S.A.E. 2335, normalized	104300	53900	39900	24900	0.52	0.74	0.46
S.A.E. 3130, normalized	100500	55100	31600	15900	0.55	0.57	0.29
S.A.E. 4130, water-quenched and drawn	128500	70100	26900	14100	0.55	0.38	0.20
S.A.E. 4615, normalized	91300	48600	33100	22400	0.53	0.68	0.46
S.A.E. 9260, normalized	143800	72100	24900	14900	0.50	0.35	0.21
Pearlitic manganese, normalized	118200	56400	29400	12100	0.48	0.52	0.21
5 per cent chrome, oil-quenched and drawn	130600	73900	52900	15500	0.57	0.72	0.21
Nickel-copper, normalized	113000	58900	26100	21900	0.52	0.44	0.37
Copper-nickel	77300	54100	33600	19600	0.70	0.62	0.36
Wrought iron	47700	30400	19600	16400	0.64	0.64	0.54
3.5 per cent nickel wrought iron	57400	39600	26900	19100	0.69	0.68	0.48
3 per cent nickel-molybdenum iron	63600	45100	25400	21900	0.71	0.56	0.49



LATHE EQUIPPED WITH VARIABLE-SPEED TRANSMISSION

MODERN HYDRAULIC UNITS *for* MACHINE TOOLS

By K. R. HERMAN

VICKERS INCORPORATED, DETROIT, MICH.

THE BASIC principles involved in applying power by hydraulic means have been known and used for many years. During much of this time applications were limited in number and variety, because the equipment built was cumbersome and operation was slow. Despite these limitations, many operations were more desirably accomplished hydraulically than otherwise.

A flurry of hydraulic development occurred prior to 1900 and many developments were made in the control of metal-cutting equipment. We believe that failure to develop low-cost, compact, reliable, and efficient pumps to some extent prevented wider acceptance and growth of hydraulic applications at that time.

The field of hydraulics received the impetus of many developments and successful applications that started about fifteen years ago. This period covers the successful development and application of units which were compact, reliable, and suitable for application to individual machines, and which became an integral part of them. At the same time their compactness made them less costly for use with central pressure systems.

The field of hydraulic application is not now limited to cumbersome, slow-moving machines, but includes light, high-speed machines, where complicated results are required.

Honing machines are now operating hydraulically as high as 1200 strokes per minute, fluid motors as high as 8000 rpm, and turbines at 50,000 to 75,000 rpm.

Hydraulic units are especially to be desired wherever tremendous mechanical reduction is desired. Either separately or combined with this feature, the ability to vary speeds and rates of travel, or to control the magnitude of the applied force at will either in advance of or during a cycle, is well-nigh impossible to secure as satisfactorily by any other method. Additional advantages are relative simplicity and the flexibility of installation where fluid conduits make the connection between elements of a machine and where mechanical connection of the parts would be much more complicated.

In order to be of service to the manufacturers and users of machinery it was necessary to develop a complete line of pumps, pressure controls, four-way valves, sequence valves, pilot valves, time delays, and flow controls, and to make compact units containing all the elements of some of the more common circuits, such as panels for boring, milling, and drilling machines.

Oil is used as the fluid medium in the hydraulic units described and it performs the double duty of lubricating the units

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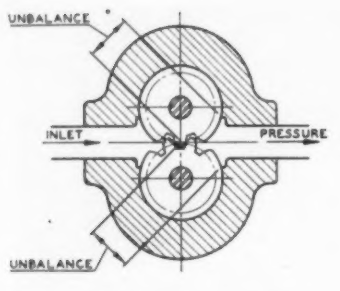


FIG. 1 UNBALANCED GEAR PUMP

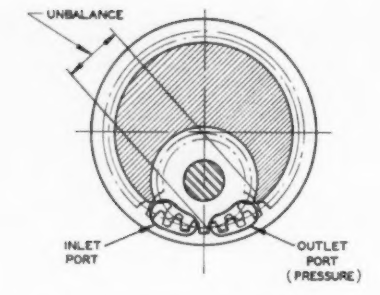


FIG. 2 UNBALANCED INTERNAL-GEAR PUMP

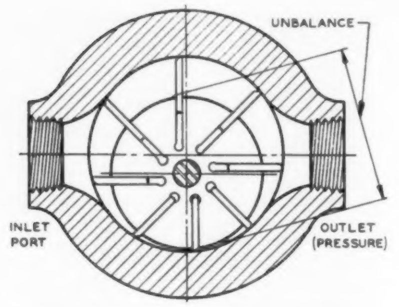


FIG. 3 UNBALANCED VANE PUMP

and transmitting the power generated by the pumps.

In developing the line of hydraulic units to attempt to fulfill the needs of machinery manufacturers, first consideration was given to the design of a suitable pump of the constant-displacement type. The most common type of pump is the gear pump. It was first considered and was then discarded because of the fact that it is unbalanced hydraulically. The unbalance extends approximately over the projected area of the gear, as has been indicated in Fig. 1. Under running conditions, the amount of pressure unbalance doubtless exceeds that on the diagram, because of the pressure distribution in the housing following up the outside of the gears on the side next to the pressure port. The internal-gear pump was also considered, but, as shown in Fig. 2, the unbalance also exists in the idler gear at least to the extent marked and probably to a greater extent, because of pressure spread on the pressure side of the gear. At least an equivalent area of the large internal gear is also pressure loaded, although the pressure loading on the pinion gear is most important because the shaft diameter must be less than the area over which pressure is spread. On both the straight-spur and the internal-gear type of gear pumps, the pressure area is considerably greater than the possible shaft diameter. Therefore, if the shaft bearings were equal to the face width of the gear, the unit bearing pressure would considerably exceed the operating pressure in the pump.

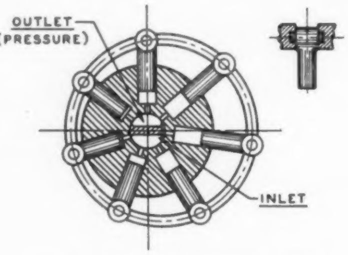


FIG. 4 MULTIPLE-PISTON PUMP

Under these conditions, if a maximum safe operating bearing load were selected of, say, 400 lb per sq in., the maximum operating pressure of the pump would have to be considerably less than this amount. Since the projected design had to be for 1000 lb per sq in. continuous operating pressure, these two types were considered unsuitable.

Another common type of pump available is the eccentric vane type, shown in Fig. 3. The unbalanced conditions of this unit are worse than those of the gear pump, and therefore, it was also eliminated.

The radial-piston type, shown in Fig. 4, possesses the disadvantages of high cost, as well as high rubbing speeds on the rollers or bearings on the outer ends of the pistons, and a pump of this type is subject to some difficulties with the rotary-valve construction in the center of the cylinder unit, because the ordinary design of this valve is unbalanced.

VANE-TYPE PUMP ADOPTED

After considerable experimentation with various types and the consideration of many designs, a vane-type pump was developed as shown in Fig. 5, in which each one of the difficulties previously mentioned was satisfactorily overcome. It will be noted that this vane-type pump has two internal inlet connections 180 deg apart, marked ports A and $A1$, and two pressure outlet connections each 90 deg from an inlet connection and 180 deg from each other marked B and $B1$. This results in a pressure balance of the rotor which carries the vanes, because A and $A1$ are of equal area and opposite each other and thus the atmospheric or subatmospheric pressures balance each other. Pressure areas B and $B1$ are also equal and balance each other. In this manner a complete pressure balance of the rotating member is secured.

The next consideration for proper design was to eliminate the wear of vanes and rotor slots that results from cantilever loading by pressure against the extended portions during the time that they were sliding in the slots. This difficulty was overcome by generating the shape of the stationary ring against which the vanes run so that radial sections extend from the inlet to the outlet ports, which cover the period during which the vane is loaded by pressure and when it is in its extended position. There are also radial sections between outlet and inlet ports in which the vane is in its retracted position. The sliding of the vanes from retracted to extended positions and from extended to retracted positions takes place during the time that a port is open to both sides of the moving vanes and the pressures on both sides of it are equal.

Because a pump which is designed for 1000 lb per sq in. must have extremely close fits and because shaft loads are often applied in a manner over which the pump manufacturer has no control, it was decided that the shaft must be entirely independent of pump parts, so that any deflection or displacement, due to wear of bearings, would have no ill effects on the elements actually doing the pumping. The shaft was therefore installed on separate bearings, as shown in Fig. 5, and because the

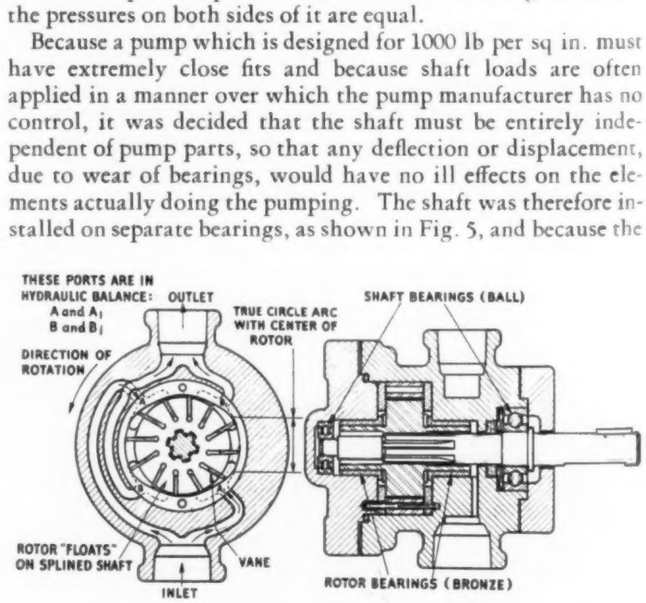


FIG. 5 VANE-PUMP CROSS SECTION

operating pressures impose no load on the rotor, it was perfectly satisfactory to support the rotor hubs in plain bearings. By making the rotor-hub bushing and valve porting plate as an integral unit, a flange-type bronze bushing was the result. An outer ring of hardened steel acted as a track for the vanes and as a spacer between the flanged bronze plates to establish definitely the running clearance of rotors and vanes. This also resulted in an attractive replacement feature, because a head can be removed and all wearing parts extracted and replaced with a complete new set of wearing parts without disconnecting the power drive from the shaft or disturbing the pipe connections to the pump body. A complete replacement of all wearing parts can thus be made in about five minutes.

Fig. 6, in conjunction with Fig. 5, makes the construction of these units clear.

Fig. 7 shows the performance curve of the vane pump just described. It should be noted that volumetric efficiency at 1000 lb per sq in. is approximately 95 per cent and that from 400 to 1000 lb per sq in. the over-all efficiency is approximately 90 per cent.

DEVELOPMENT OF RELIEF VALVE

Following the development of a satisfactory pump, it was next necessary to have a relief or pressure-control valve. Valves of ordinary type, shown in Fig. 8, are subject to considerable chattering, especially at higher pressures, and at a given adjustment the relieving pressure will vary with the volume being passed through them. They also will give different pressure readings when rising and falling volumes of oil are passed through them. In Fig. 9 is a characteristic curve of this type.

In order to overcome these difficulties a valve, shown in Fig. 10, was developed. It has a small ball-type relief valve acting as a pilot valve to control the main valve. The oil which flows over this pilot control valve is only that which passes through the small orifice in the large piston and is always the same in volume.

The large valve is held on its seat by a light spring and the pressure which exists in the main passageway also exists on top of the piston and is communicated through the small orifice in the large piston. No flow takes place through this orifice until pressure reaches the point where the pilot pressure-control valve is forced off its seat. At this time pressure above the large piston is prevented from rising any higher as any tendency to rise will cause oil to be passed over the pilot relief. Therefore, any increase in pressure below the large piston will cause a pressure differential between two sides of the large piston and raise the valve, which is attached to the large piston, from its seat. Likewise, with any reduction in pressure below the set value, flow over the pilot relief stops and the spring on the large piston carries it back to its seat. The small amount of flow necessary to fill the upper chamber takes place through the small orifice. A characteristic curve of a valve of this type is shown in Fig. 11, and in addition to this favorable performance curve, no difficulty is encountered with chatter, as the piston is damped by the small orifice.

MANY TYPES OF VALVES DEVELOPED

A number of types of four-way valves, including manually operated, pilot-operated, solenoid-operated, and latch and fire types of valves of balanced-spool design were a necessary addi-

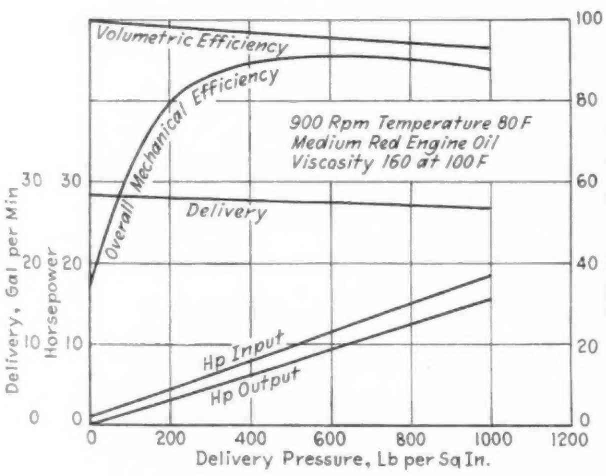


FIG. 7 PERFORMANCE CURVE OF VANE PUMPS

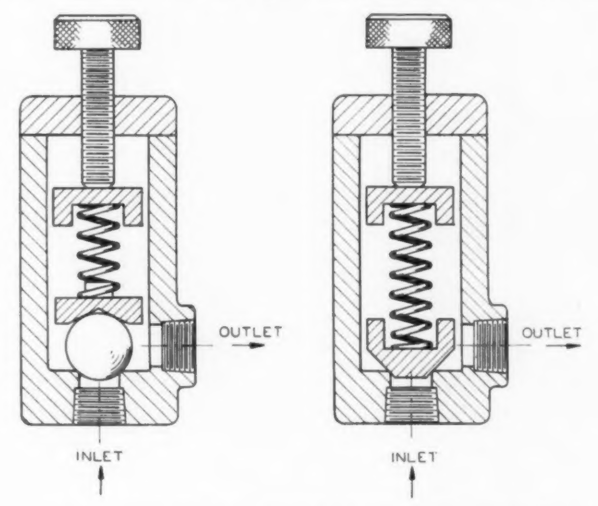


FIG. 8 TWO TYPES OF SPRING-LOADED RELIEF VALVES

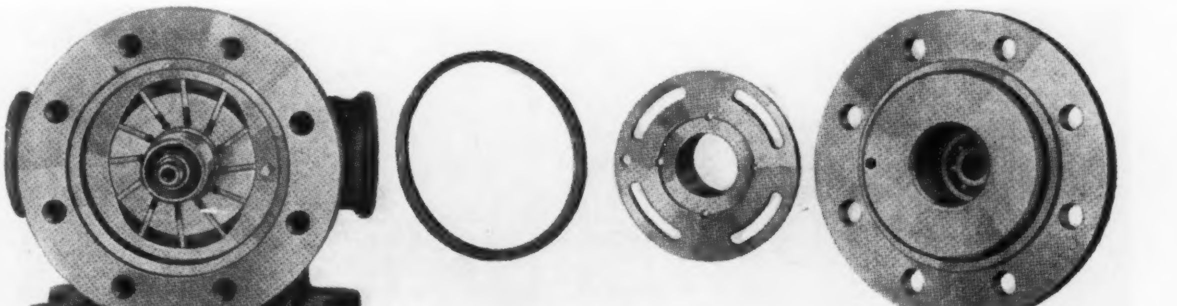


FIG. 6 PRINCIPAL PARTS OF THE VANE PUMP

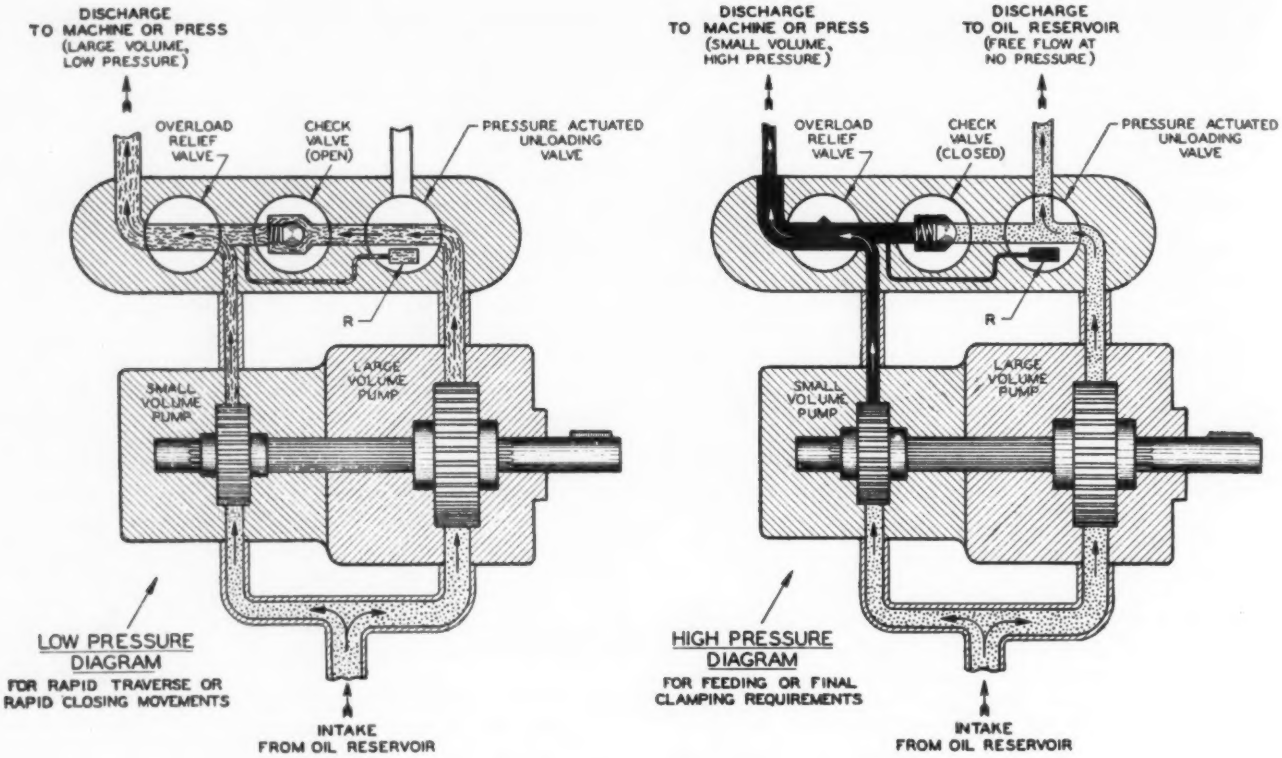


FIG. 12 DOUBLE PUMP FLOW DIAGRAM (161-S)

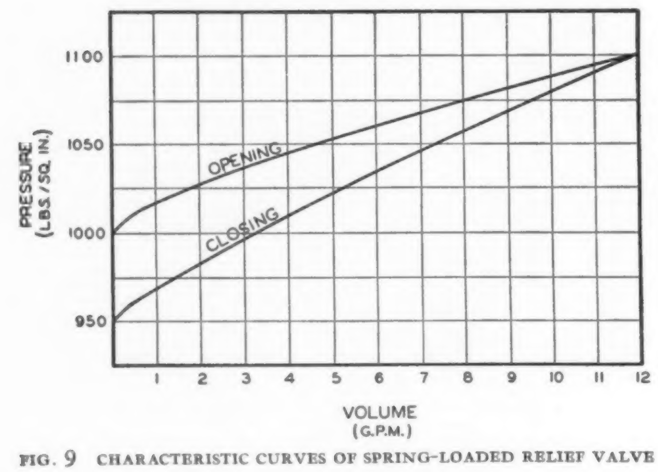


FIG. 9 CHARACTERISTIC CURVES OF SPRING-LOADED RELIEF VALVE

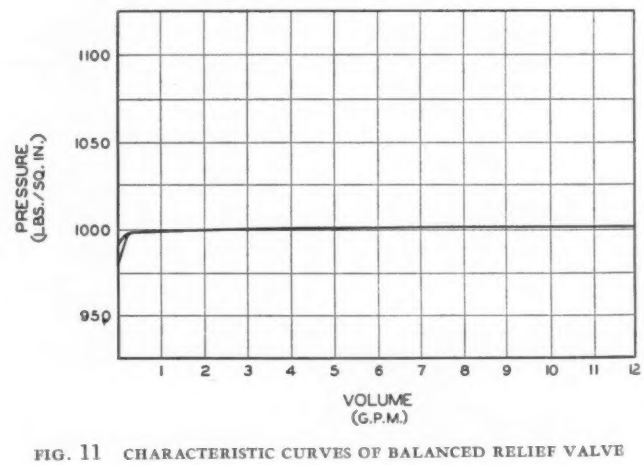


FIG. 11 CHARACTERISTIC CURVES OF BALANCED RELIEF VALVE

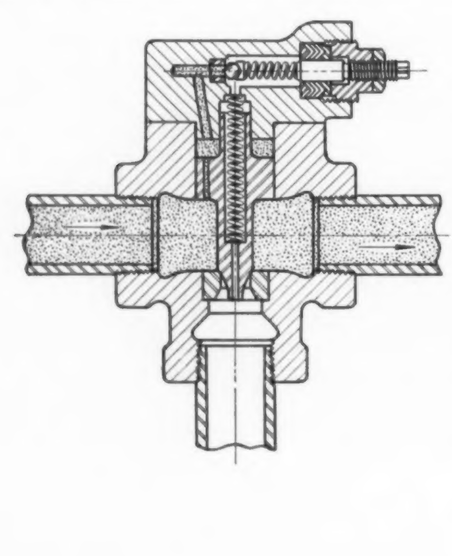
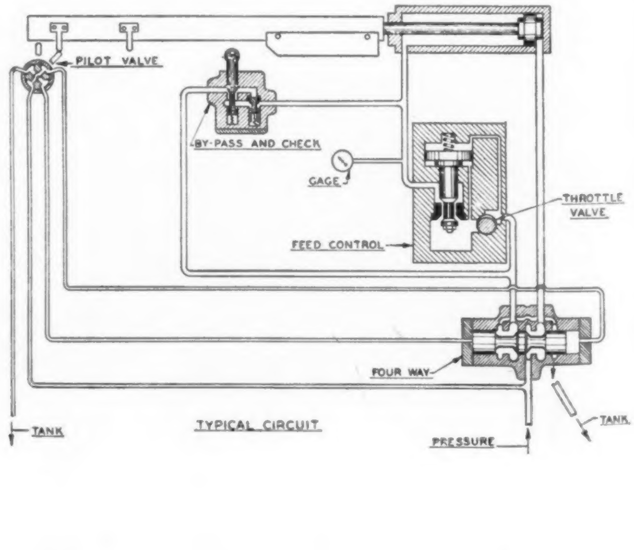


FIG. 10 (LEFT) CROSS SECTION OF RELIEF VALVE DEVELOPED

FIG. 13 (RIGHT) CIRCUIT DIAGRAM FOR FEED CONTROL



tion to the line. Aside from considerable research into materials the designs follow well-known principles and are not of sufficient interest to justify extended description.

Small rotary-type, balanced pilot valves for operating the large four-ways were also developed. One of the common problems to be solved in applying hydraulics to forming or molding presses was the large volumes required for rapidly approaching the work at which time relatively low pressures were needed, and the development of high pressure for doing the work or maintaining pressure. The second part of the cycle requires a high pressure and only sufficient volume to form a part or to overcome leakage. While large, variable-volume pumps have been used for such purposes, operated at reduced stroke during high pressures, it seemed that a combination of two constant-volume pumps could be developed for this purpose, as these would be more economical to build and would satisfy all the requirements. As a result, a combination of two pumps and an automatic pressure-controlled valve was developed. By referring to Fig. 12 it will be seen that the combined volumes of two pumps are available until such time as the control pressure in the chamber *R* reaches a predetermined value, at which time the large-volume pump is unloaded and allowed to return to the reservoir at no pressure, so that the high pressure might be supplied by the small-volume pump with a consequent reduction in power requirement.

For pressures higher than 1000 lb per sq in. a two-stage vane-type pump was developed with an automatic dividing valve to divide the load equally between the two stages. Without this automatic valve, one stage will always pick up the entire load.

FEED-RATE CONTROL

For the purpose of controlling feed rates on installations with constant-volume pumps, it has been customary in the past to use a needle valve or similar valve as a throttle on machine tools, such as drilling and milling machines. The use of an ordinary throttle valve was considered unsatisfactory because the flow through any orifice depends on the pressure drop across the orifice. Thus, if a needle valve is used to control the feed rate of a drilling machine, the pressure drop across the valve will vary with the resistance encountered at the drills. This is a particularly bad condition when a drill is breaking through the work, as it results in a "lunge" of the drill spindle and in many broken drills. It was therefore decided that a metering device had to be developed that would be independent of pressure changes and it was also decided that this metering device would be most desirable if installed on the outlet side of the cylinder. This would prevent the machine-tool head from "running away" from the hydraulic fluid and would result in locking the piston between two volumes of oil under pressure. It would permit of such difficult operations as climb-cut milling.

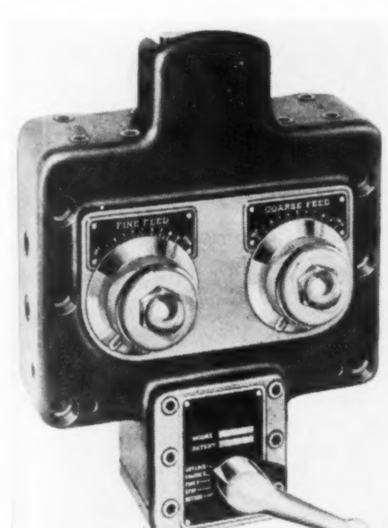


FIG. 14 PANEL FOR RAPID APPROACH, COARSE AND FINE FEED, AND RAPID RETURN

The basic circuit developed is shown in Fig. 13, which illustrates diagrammatically the cylinder and work slide, pilot valve for automatic reversal, pilot-operated four-way valve, metering control, and a by-pass for metering control to secure rapid traverse in the forward direction. The metering or feed control contains an automatic valve with connections from each side of the throttle valve arranged so that the automatic valve controls the pressure drop across the throttle valve and maintains it at a uniform amount. The pressure drop ordinarily allowed across the throttle valve is 20 lb per sq in. This low value permits relatively large throttle openings for small volumes and eliminates possibility of clogging when the required feed rate is very slow.

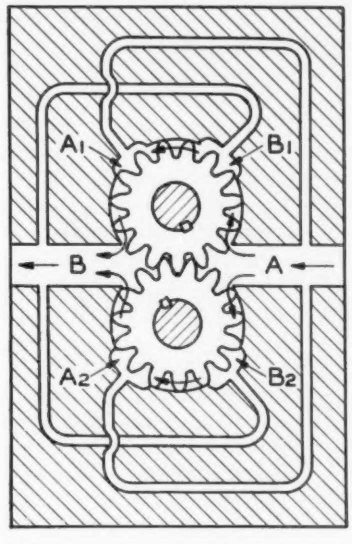


FIG. 15 DIAGRAMMATIC SKETCH OF FLUID-MOTOR CIRCUIT

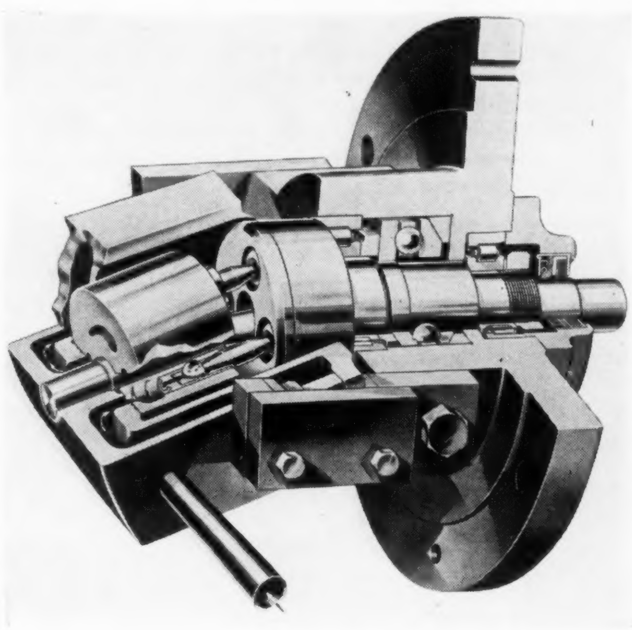


FIG. 16 VARIABLE DELIVERY PUMP

In order to simplify the mechanical construction and for ease of installation, the more commonly used circuits were designed into panel units. In Fig. 14 is illustrated one of these panels for rapid approach, coarse feed, fine feed, and rapid return. Both of the feed rates are individually adjustable to any desired rate.

DEVELOPMENT OF FLUID MOTOR

At this point sufficient equipment had been developed to take care of most installations in which a cylinder is used as

the final means of delivering power. Since many installations require rotary movement, it now became necessary to develop a fluid motor. Many types of fluid motors were considered and several of them were built and tested. The one which was finally considered satisfactory was an ordinary spur-gear type such as might be used for a pump, but with the hydraulic forces as shown in Fig. 1 completely balanced out as shown in Fig. 15. It will be noted that chamber *A* is balanced by chambers *A*1 and *A*2, and that chamber *B* is balanced by chambers *B*1 and *B*2. This method of balancing results in a motor that will start under full load, that is simple and compact in construction, and that is capable of high speeds.

VARIABLE-VOLUME PUMP

For the purpose of handling high horsepowers, where a variable-volume pump is required, and for large hydraulic transmissions of the variable-speed type, the unit shown in Fig. 16 was adopted. The engineering reasons for adopting this design were as follows:

1 The shaft bearings are small in diameter so that even at high rotating speeds the bearing speeds are low.

2 The valve surface is flat and automatically compensates for wear. It is also counterbalanced hydraulically, so that the load on the valve surface is low.

3 The unit includes a means for lubricating the connecting-rod ball ends on the inlet stroke, which permits high operating pressures without bearing failure.

4 The force necessary for varying the stroke when running under load is small. This unit is suitable for intermittent loads up to 3000 lb per sq in.

The illustration on the title page of this paper shows a large lathe driven by a variable-speed transmission. It will be noted that this lathe has a tachometer on the spindle. The tachometer dial has a number of scales, showing the cutting speeds for various diameters, so that the operator may quickly choose the proper cutting speed for the diameter of the piece being turned.

Fatigue and Corrosion Fatigue of Steels

(*Continued from page 822*)

pointed out the rôle of surface films in determining the rate of corrosion of steel. As these films are composed of corrosion products and are very thin, they have but little mechanical strength. The increased corrosion rate of metal under cyclic stresses is then undoubtedly due to the rupture of these films which otherwise would exert some protective action. This reasoning may be extended to any type of protective coating such as paint, electroplated, sprayed, or hot-dipped metallic coatings. If such coatings are impermeable and not ruptured under cyclic stressing to which they are subjected, they may be expected to protect the steel from damage by corrosion fatigue. But if they are not able to withstand these forces without mechanical failure they will be ineffective as protective agents or, under some conditions, they may, through the formation of concentration cells, actually accentuate the damage.

Many aspects of a very broad subject, any one of which might well be considered at greater length than this entire article, have been discussed in brief and if it is able to raise more questions than to provide answers, thereby stimulating further investigation, the effort expended in its preparation will have been more than repaid.

ACKNOWLEDGMENT

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ELECTRIC LOCOMOTIVES

The Trend of Recent Design and Practice

By B. S. CAIN

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THE PROGRESS of electric-locomotive design in the United States is marked by three major phases. In the early days the chief reason for using electric locomotives was generally the elimination of smoke in tunnels and terminals such as those in New York, Baltimore, and Detroit. The second stage involved electrification, especially on heavy grades, where electric locomotives replaced steam locomotives to permit of higher speed performance and lower operating costs. Mountain-grade operation is difficult for steam power as slow-speed operation can only be obtained at high values of tractive effort. There is the additional advantage that electric locomotives can be built with regenerative electric braking which allows trains to be handled downgrade safely at higher speeds than with steam and without destructive wear on brake shoes and tires.

The third and present phase of electric-locomotive development covers main-line heavy-schedule train operation in which electric operation cannot be equaled by any other form of motive power. The key to improved service is high power output, which is necessary for the high speed, incident to modern schedules and rapid acceleration. In addition there is obtained the reliability, which is necessary for economical mass transportation and for on-time performance. To illustrate some steps in electric-locomotive development, a few typical examples are given in Table 1. The earlier locomotives of the New York Central and New Haven railroads represent the first designs to be built in any quantity in this country. The New York Central used 600 volts direct current and the New Haven 11,000 volts alternating current. Both locomotives had gearless motors, the New York Central with bipolar armatures directly on the axles and the New Haven with multipolar motors and spring drives. In a later phase of development, current practice is represented by the passenger and freight locomotives of the Chicago, Milwaukee, and St. Paul running on 3000 volts direct current and the class 0300 passenger locomotives of the New Haven using 11,000 volts alternating current. All these locomotives were geared except the bipolar gearless passenger locomotives of the Milwaukee and all had different wheel arrangements.

Examples of modern design are the class GG-1 passenger locomotives of the Pennsylvania and the classes 0351 and 0361 of the New Haven. All of these operate on 11,000 volts alternating current and have the same wheel arrangement, six drivers in two articulated trucks with a two-axle guiding truck at each end. All have geared twin motors with spring drive.

Over a period of roughly thirty years the continuous horsepower of representative designs has increased from about 1000 to between 4000 and 5000. The weight per continuous horsepower has decreased from about 250 to about 100 pounds. These figures illustrate one of the major trends of recent designs, the steady increase in horsepower with a much smaller increase in weight, which is made necessary by the imperative demand for higher train weights and higher sustained speeds on the American railroads.

TABLE 1 ELECTRIC-LOCOMOTIVE DEVELOPMENT

Railroad and class	Year in service	Contact line	Wheel arrangement	Weight in 1000 lb On drivers	Weight in 1000 lb Total	Maximum speed, mph	Continuous hp at mph	Lb per continuous hp
N.Y.C., class S	1906	600 v dc	2-D-2	139	225	60	792 at 61	284
N.Y. N.H. & H., 01-041	1907	11000 v ac	1-B + B-1	167	217	88	1016 at 73	214
C.M.St.P. & P., freight	1915	3000 v dc	2-B + B + B + B-2	225	288	35	1670 at 15.5	172
C.M.St.P. & P., geared passenger	1920	3000 v dc	2-C-1 + 1-C-2	378	600	65	3400 at 31.2	176
C.M.St.P. & P., bipolar	1920	3000 v dc	1-B + D + D + B-1	457	521	90	3360 at 36.9	155
N.Y. N.H. & H., 0300	1919	11000 v ac	1-C-1 + 1-C-1	233	349	66	2004 at 54.4	174
N.Y. N.H. & H., 0351	1931	11000 v ac	2-C + C-2	270	404	70	2740 at 55.0	147
P.R.R., GG-1	1935	11000 v ac	2-C + C-2	306	454	90	4620 at 54.0	98
N.Y. N.H. & H., 0361	1938	11000 v ac	2-C + C-2	270	432	90	3600 at 55.8	120

POWER SUPPLY

The direct-current system was the first to be improved by the raising of line voltage to 3000. This made it possible to collect any reasonable amount of power from the overhead line. More recently, improvements have been made in alternating-current motors so that their starting torque and commutator life are comparable with those of direct-current motors.

Whichever system is used, the electric locomotive has a most important characteristic in that the nominal rated power can be greatly exceeded for short periods, particularly at medium speeds. A locomotive which rates 5000 hp continuously can develop something like 10,000 hp for short periods. This has two major advantages; first, the electric locomotive can accelerate its train more rapidly than the steam and at higher speeds because the horsepower continues to rise as the speed increases and, second, the train speed can be kept up on a rolling profile, because, on light grades, the extra horsepower can be used so long as the average heating of the equipment is not excessive.

To take an example, Fig. 1 shows the power obtainable from a steam locomotive and from an electric locomotive having ap-

Contributed by the Railroad Division for presentation at the Annual Meeting, New York, N. Y, December 5–9, 1938, of The American Society of Mechanical Engineers.

proximately the same power at high speed. The shaded area shows the extra performance available in the electric locomotive for faster acceleration and for maintenance of higher average speeds. A similar comparison can be made between electric locomotives and those with Diesel-electric or similar self-contained power. The self-contained power unit has a characteristic quite similar to that of the steam locomotive except that as soon as the speed is high enough to develop the full rating, the power remains nearly constant, as shown by the dotted line in Fig. 1. This comparison means that the electric locomotive can make real use of the capacity of the external electric-power system, a reserve of power which is of course not available to any self-contained unit.

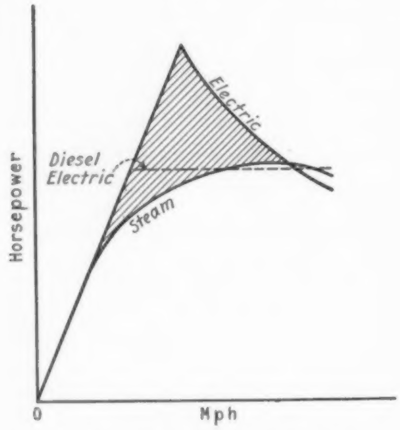

FIG. 1 HORSEPOWER–SPEED CHARACTERISTICS OF STEAM, ELECTRIC, AND DIESEL-ELECTRIC LOCOMOTIVES

HIGH SPEED

The spectacular achievements of recent electrification are mostly in high-speed passenger service. The concentration of power permits increased speed and acceleration of heavy trains which is difficult to equal by other means. As speeds increase, the advantages of moderate axle loads, perfectly balanced drive, and the absence of reciprocating parts weigh more and more in favor of electric drive over other types both on electric locomotives and on self-contained streamlined trains.

Although this passenger business attracts more general attention, the advances being made in fast freight service are perhaps more important. Speeding up freight trains to from 50 to 70 mph is bringing about revolutionary changes in railroad operation.

The first change found, when operating fast freights over a rolling profile, is that the momentum of the train allows grades to be overcome more easily than if the train were dragged up slowly. This applies especially to electrically hauled trains because of the low friction of the electric locomotive. It applies less to steam trains since the momentum must overcome more locomotive friction.

The effect of speed on momentum grades can be studied by using the formula

$$F \times L = (V_1^2 - V_2^2)/70$$

where F = the effective reduction in train resistance in lb per ton
L = the length of the grade in miles
V_1 = speed at the bottom of the grade, mph
V_2 = speed at the top of the grade, mph

For example, if a train approaches a 2-mile upgrade of 0.8 per cent at 50 mph and the speed drops to 20 mph at the top, then L = 2 miles, V_1 = 50 mph, V_2 = 20 mph, and $F = (2500 - 400)/(70 \times 2) = 2100/140 = 15$ lb per ton.

The 0.8 per cent grade produces a resistance of 16 lb per ton, and $16 - 15 = 1$ lb per ton, which is all that is left of the grade resistance if the train decelerates from 50 to 20 mph. In other words, a locomotive which can haul this train at 50 mph on the level can take a 2-mile 0.8 per cent grade by momentum.

The effect increases rapidly with the train speed and the important result is that it is practical, on rolling profiles, to use high-speed electric passenger locomotives in fast-freight service. A comparison of the tonnage ratings of a locomotive geared for example for 90-mph passenger service with one geared for 70-mph freight service will show that, in many applications, there is not enough difference to warrant two kinds of locomotives and the passenger and fast-freight power can be pooled. The advantages in reducing stand-by power, increasing locomotive mileage, and providing for seasonal requirements will be obvious.

MOTIVE-POWER TRANSFERS

An analysis of the use of motive power on most railroads will show that power stands idle many hours because it is either of the wrong kind or is situated at the wrong place for the immediate requirements of the traffic. The advantage of high-speed electric locomotives which can be pooled for both freight and passenger service has already been mentioned. This is a step toward having the right kind of locomotive available by reducing the number of kinds which are necessary. Another step toward intensive use of power is the systematic transfer of locomotives to points where they are needed. This is expensive with steam power on account of the crew expense and fuel cost involved in transfer. Most electric locomotives, however, are designed for multiple-unit operation so that no crew expense and only moderate power costs are involved. In this way regular train movements are used to distribute motive power over the system as it is wanted and the utilization of each unit is increased with consequent savings in the number of locomotives required to handle the traffic.

LOCOMOTIVE ADHESION

As speeds and powers have increased, electric locomotives have been built which can exert high tractive effort at fairly high speeds. It is possible to obtain 25 per cent adhesion at 50 mph on some units although this is not relied on. It does not appear possible to obtain regularly adhesions of over 20 per cent at 30 mph with reasonable rail conditions. As the power per ton of driver weight increases, we are getting more experience to show what the limits of adhesion at speed really are. So far results are encouraging, in that speed seems to have less effect than was thought when high tractive effort was not available at high speed. One well-known factor which works toward the practical use of high adhesions at speed is that if the wheels slip, momentum will prevent the train stalling before the traction is restored. At low speeds a slip may mean a stall and greater margin of safety is necessary.

To detect slipping, suitable relays are now commonly included in electric-locomotive control.

DRIVE

Electric drives in recent years have been principally of two kinds, either geared drive from axle-supported motors or geared-quill drive from frame-supported motors. The quill drives have nearly all been through spring cups. In some cases rubber has been used in place of the spring cups and favorable results have been reported. Quill drives have sometimes been advocated as a means of reducing the unsprung weight. It is found, however, that the larger wheels and larger axles necessary with quill drives result in unsprung weight comparable with that of the smaller wheels and axles and the unsprung part of an axle-supported motor. The experience with large axle-supported motors at fairly high speeds and of the somewhat smaller motors

on high-speed streamline trains has encouraged designers to use axle-supported motors wherever possible on account of their relative simplicity and ease of maintenance.

Where more horsepower is required on an axle than can conveniently be provided with one motor, then twin motors are used with quill drive. The usual limit of horsepower for a single motor has been between 600 and 700 hp. The power which can be used on a 50,000-lb axle is over 1000 hp so that both axle-hung and quill-mounted motors are likely to continue in use.

A definite improvement in the manufacture of gears has taken place in recent years. This allows single gears to be used where twin gears previously were necessary. It is also possible to use solid gears in place of cushion gears, due to the superior accuracy with which the teeth are cut.

RIDING QUALITIES

The demand for sustained speed has made it necessary to build locomotives which ride easily without damage to track, not only on normal well-maintained track, but over rough stretches which may be met. As a result of many tests with accurate recording instruments, the behavior of a number of common electric-locomotive types is now well understood. Two main types of high-speed electric locomotive have been built in this country, the frame type, in which all drivers are in one rigid frame, and the articulated type with a cab mounted on center plates. The characteristics of the two kinds are quite different. The frame type tends to run stably on good tangent track, but to nose on high-speed curves. On rough track the lateral blows are likely to be high because of the rigidity of the structure. The articulated locomotive is exactly the opposite. It has a tendency to nose on straight track, but runs steadily on curves, with low flange forces. On rough track the division of the mass into separate parts tends to reduce the blow at any one wheel.

Both types of locomotive are now built with guiding trucks of special design. These have high initial resistance to side motion and radius bars to prevent nosing. The lateral restraint decreases with increasing side motion so as to avoid high flange pressures on sharp curves. The radius bars are held by spring cushions, which allow motion if a certain force on the bar is exceeded. This prevents binding under special track conditions.

A similar spring-cushioned restraining bar is used between the cab and driving trucks on high-speed articulated locomotives. This holds the trucks steady on straight track, but exerts no force on moderate or sharp curves.

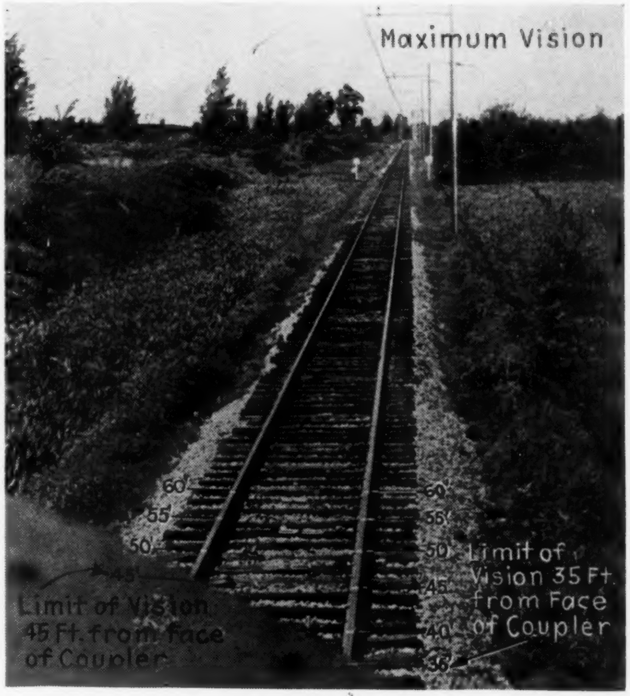

FIG. 3 VIEW FROM CAB OF LOCOMOTIVE SHOWN IN FIG. 2

With these stabilizing devices, successful experience has been obtained with 2-B + B-2 and particularly with 2-C + C-2 locomotives.

On rigid-frame locomotives the most effective designs include free lateral motion of the center drivers of the order of 2 in., with these drivers flanged, and restrained lateral motion of the end drivers. The free center drivers increase the stability of the locomotive both on straight track and on curves. The restrained lateral motion on the end drivers provides a cushion at rough spots in the track and reduces the maximum blows. This cushioning is of course lost if the track is so rough that the available lateral play is completely taken up and the cushion is followed by impact. Both springs and inclined planes have been used to restrain lateral motion.

High-speed Diesel-electric locomotives have not followed electric-locomotive design, but are similar to passenger cars, with two- or three-axle swing-bolster trucks.

FIG. 2 STREAMLINED ELECTRIC PASSENGER LOCOMOTIVE

APPEARANCE

Electric locomotives have not escaped the universal vogue of streamlining. In most cases styling rather than true streamlining has been the object. There is reason for this, because the public has shown an extraordinary interest in the appearance of recent electric power and because true streamlining, to be effective, must include the train as a whole rather than just the locomotive.

In styling a locomotive, the designer must consider many things besides good lines and low wind resistance. Vision for the operator is most important. The majority of earlier high-speed locomotives had operating cabs at the extreme ends, so that vision was excellent. There has been a tendency recently to move the operator back, sometimes to improve the arrangement of equipment and sometimes to give protection by putting an equipment cab ahead of the opera-

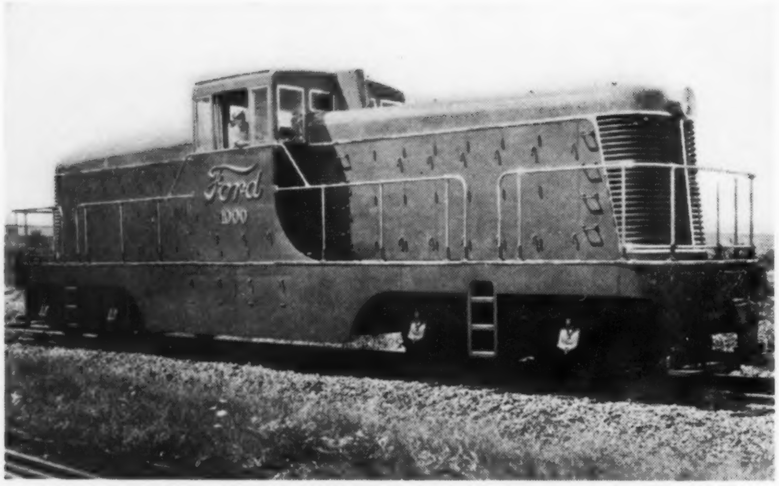

FIG. 4 STREAMLINED DIESEL-ELECTRIC SWITCHING LOCOMOTIVE

tors. In this case good vision becomes a determining factor in design. Fig. 2 shows one of the most recent streamlined locomotives of the New Haven Railroad and Fig. 3 shows the view from the operator's position.

Styling is not confined to high-speed passenger locomotives as will be seen from Fig. 4, which shows a Diesel-electric switching locomotive.

Another factor to be considered in some cases is dust. A high-speed train in a slight side wind tends to roll up a great wedge of entrained air on the leeward side which is a low-pressure region. On some roadbeds this results in a cloud of dust and gravel, appearing to rise from the locomotive wheels and becoming higher and wider as it goes back, until it covers the whole leeward side of the train. To prevent this dust cloud it is necessary first to promote easy air flow across the train, so as to avoid a low pressure on the leeward side and, second, to provide a downward flow of air on to the roadbed which will keep the dust from rising.

Air flow from one side of the train to the other is helped by omitting closed coverings on the trucks or under the body and by rounding the roof and underside of the body as much as possible. A down draft on the roadbed is helped by suitable shaping of the front end and by deflectors under the body, which direct cross winds in a downward direction.

Improved appearance has also been obtained by using a disappearing coupler on the front end of some locomotives. This is actually required to avoid entanglement with automobiles in cases of collision but incidentally gives a smooth appearance to the pilot. In some cases the coupler swings down; in others it slides back into the housing.

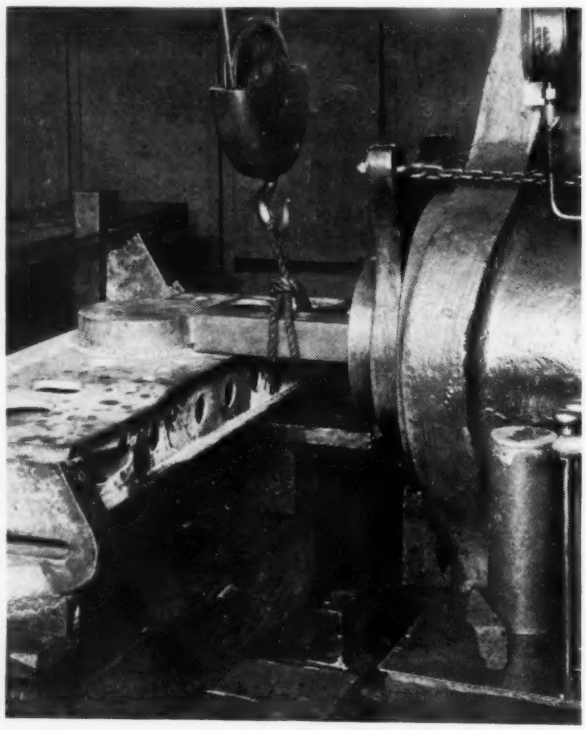

FIG. 5 CAB BOLSTER UNDER TEST

MECHANICAL CONSTRUCTION

For some years there has been a steady tendency away from riveted or bolted construction of truck and cab frames. These parts are now almost all cast or welded. Some use has been made of high-strength steels as a result of the necessity for saving weight in high-powered units.

Fig. 5 shows a half-size sample cab bolster and centerplate being tested to destruction. This is a complicated structure fabricated by welding of high-strength steel and subjected in service to a combination of bending and twisting. The sample was tested in a press, using strain gages to map the stresses throughout the structure. It was finally loaded until it took a permanent distortion. Fig. 6 shows the bolster distorted after being put under a test equivalent to 1,500,000 lb buffing load on the locomotive. Tests like this are useful in locating weak spots in a complicated structure but they do not give much indication of possible fatigue failures due to local concentrations of stress. Careful design is necessary to avoid this.

Fig. 7 shows the fabricated cab underframe of an all-welded switching locomotive.

There has been one recent innovation in truck construction which, although used on internal-power locomotives, could be applied equally well to electrics. It was formerly the custom to install couplers and draft gear on the truck frames of articulated locomotives and on the cab underframes of locomotives with free-swiveling trucks in order to avoid transmitting buffing and traction forces through the cab center-

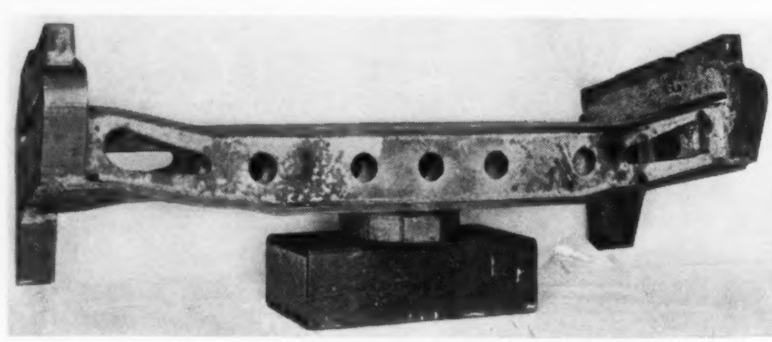

FIG. 6 BOLSTER DISTORTED AFTER FINAL TEST

plates. In several recent designs the draft gear is on the truck frames although the trucks are not articulated. The integral construction of cab underframes and centerplates allows this to be done and no trouble has been experienced. The design reduces coupler swings as well as the weight of the underframe.

The chief advances in cab construction have been in devising streamline contours which can be built without excessive manufacturing cost and in developing the technique of welding cab frames and sheets to get a smooth appearance and adequate strength. Long cabs are built with trusses to carry the load between centerplates. In some cases the trusses formed part of the central apparatus compartment, but more recent designs use trusses in the outside cab walls so as to provide more accessibility between the side aisles and the apparatus.

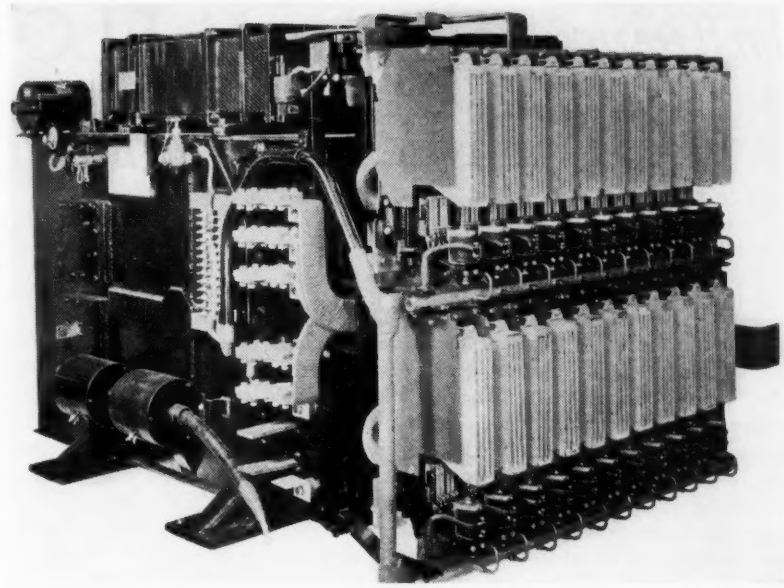

FIG. 8 ALTERNATING-CURRENT VOLTAGE-CONTROL UNIT

ARRANGEMENT OF APPARATUS

The tendency in electric-locomotive design is to assemble the electric control as far as possible in groups and to pipe and wire these completely before installing them in the cab. Resistors, shunts, transformers, and other equipment containing no moving parts and requiring infrequent inspection and maintenance are, where possible, force-ventilated, insulated with class B insulation, and connected in units with brazed joints. Generally it is necessary to take a complete unit out of the locomotive in case of failure, just as it is necessary to remove a traction motor to replace a field coil. However, contactors and other equipment with moving parts which require periodic maintenance are mounted in the units so as to be readily accessible and can be removed individually. This method makes far more compact assembly of high power in a limited space, provides the minimum of assembly work to be done in the cab itself, and facilitates maintenance by using space only where it is needed. A typical unit, for alternating current voltage control, is shown in Fig. 8.

Ventilation of electrical equipment has made some progress toward the aim of supplying clean dry air. Three lines of attack have been used. The first is to use effective louvers with labyrinth openings or oiled surfaces to remove dirt and water from incoming air.

The second method is to take incoming air through rotary cleaners built into the blowers. Blowers can be obtained which separate a high percentage of dirt and water and deliver relatively clean air to the locomotive air ducts. These blowers are larger than they would otherwise be and may be more noisy, so that they cannot be used in all cases.

The third method is to put large air intakes in the roof of the locomotive, with rain baffles and screens. The air at this height is generally clean and if large air scoops can be used it is possible to obtain some positive pressure inside the cab at high speeds, which keeps dirt from filtering in.

ACKNOWLEDGMENT

I wish to express my thanks to E. W. Brandenstein and R. Walsh, both of the General Electric Company, who have made valuable suggestions during the preparation of this paper.

FIG. 7 FABRICATED CAB UNDERFRAME FOR ALL-WELDED SWITCHERS

Influence of STEAM-FLOW METERING EQUIPMENT *on* PIPING DESIGN

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ONE OF THE features of modern power plants often neglected in the initial stages of design is that of steam-flow measurement. The use of large-capacity steam equipment in modern stations with attendant increases in steam velocity tends to complicate the problem of satisfactory metering installation. Proper consideration of this question by the piping designer and meter experts, in the early stage of piping studies, can nearly always result in a better and more economical installation than when selection of nozzle or orifice-plate locations is delayed until the piping design is completed and perhaps in the process of fabrication.

It is hoped that this paper will serve to focus the attention of those responsible for station design on this question of steam-flow measurement. The elimination of expensive water-weighing equipment and the general acceptance of steam-flow measurements by both manufacturers and users as a criterion of turbine and boiler performance lends importance to this phase of plant design. This use of flow measurements instead of water weights for acceptance testing has resulted from a better understanding of the various factors influencing accuracy.

Two of these factors are directly related to the piping design. The first is that of nozzle or orifice-plate diameter ratio, D_2/D_1; that is, the nozzle or orifice-plate throat diameter, D_2, divided by the inside pipe diameter, D_1. If a diameter ratio much greater than 0.7 is used, flow through the throat is apt to be erratic over a range of steam flow, partly due to pipe-wall roughness, and the use of the "estimated" flow coefficients may result in considerable error in the total quantity. On the other hand; the use of a nozzle with a low diameter ratio may result in a large net pressure drop and the use of an expensive high-differential-pressure secondary element, neither of which would be acceptable in most piping designs. The piping-designer's problem then becomes one of selecting the economical line size based on the allowable over-all pressure drop and the cost of the pipe, which should include as well, the meter-installation cost. Several cases with which the author is familiar permitted the use of pipe a size larger than that dictated by the pressure-drop requirements, at some saving in cost, because a secondary metering element for a lower head could be utilized.

The second of these factors is that of location of the nozzle or orifice plate in the pipe line to permit satisfactory upstream and downstream flow conditions. Although much is still unknown as to the disturbing influence caused by eddies and swirls resulting from pipe bends and fittings which may be in the line ahead of the primary device, certain minimum conditions as to the amount of straight pipe before and after the nozzle have been established by experimenters. Several typical nozzle locations with different piping arrangements are shown in Fig. 1. The values given are those which have been established by experi-

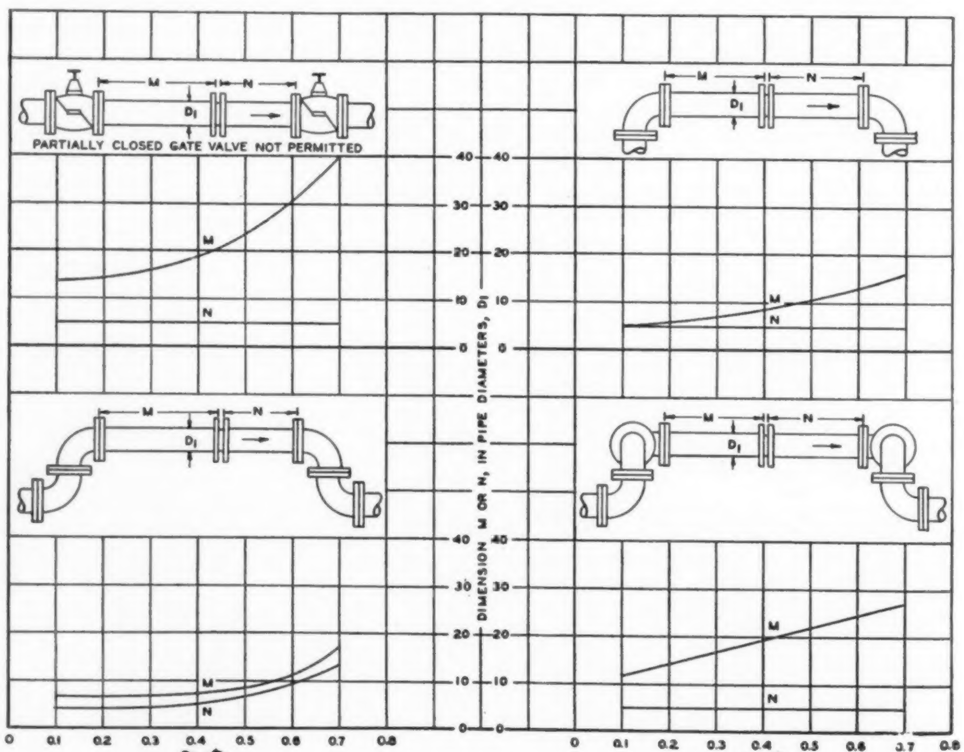

FIG. 1 MINIMUM LENGTHS OF STRAIGHT PIPE FOR UNDISTURBED FLOW WITHOUT STRAIGHTENERS

(For nozzle and orifice-plate installations. D_1 = inside pipe diameter, D_2 = diameter of throat of nozzle or orifice plate. From A.S.M.E. "Instruments and Apparatus," Part 5, Chapter 4. Based on Figs. 1 to 5, Report of the Joint A.G.A.-A.S.M.E. Committee on Orifice Coefficients, 1935; and Figs. 27, 27-*a*, 28, and 29, "Durchflusszahlen von Düsen und Staurändern," by R. Witte, *Technische Mechanik und Thermodynamik*, vol. 1, March, 1930, p. 113.)

Contributed by the A.S.M.E. Special Research Committee on Fluid Meters for presentation at the Annual Meeting of The American Society of Mechanical Engineers, New York, N. Y., December 5-9, 1938.

ment to give dependable flow coefficients, and are the best available at the present time. Whenever there may be doubt as to whether undisturbed flow is obtained, the use of a straightening vane in addition to the minimum lengths of straight pipe is advisable. This is particularly true where the primary element is preceded by bends in more than one plane. It is difficult, even with long lengths of straight pipe, to eliminate the double swirls set up.

To those familiar with flowmeter practice, these considerations are common knowledge. Piping designers, as a rule however, are unaware of their effects on flow-measurement accuracy. The meter manufacturer accordingly, if not consulted in the initial stages of the piping design, may be forced to supply more expensive equipment to obtain a given range of accuracy than would have been necessary had the designer a better understanding of the problem. Again it is possible that the piping layout may have to be changed to obtain a satisfactory location for the primary element.

In this connection it might be well to add that, from a user's standpoint, it would be well for the meter manufacturers in installation instructions to list the magnitude of the probable metering errors involved if all the various precautions are not taken in the installation of both the primary and secondary elements. It is realized, of course, that the magnitude of errors involved for certain conditions is not known. Why, however, cannot approximations be given?

The condition of the pipe preceding the nozzle also should receive consideration, although the error involved in the measured quantities may be small. The inside surface of the pipe should be as smooth as possible and, if necessary, should be cleaned to remove mill scale or scale resulting from heat-treatment. A smooth inside surface is of particular importance in the smaller pipe sizes. The variation in diameter should be as small as possible to insure concentric alignment of the nozzle or orifice-plate throat. The diameter of tubing purchased under A.S.T.M. Specification A106 or A206 in sizes from 10 to 18 in., inclusive, may vary as much as $^1/_8$ in. at any transverse section. It is usually possible to select the most concentric pipe fillers from those available for the piping system for use preceding the primary device.

There is now available for use in welded pipe lines, a machined section of pipe with integral nozzle ready for insertion between pipe fillers. This should be an improvement over most of the accepted methods of primary-element installation, provided upset pipe ends and a recessed backing ring or similar construction is used to prevent inside obstruction at the upstream joint. In the installation of either the nozzle or orifice plate there is no difference except in the case where vanstone or seal-welded-joint construction with long-hub loose companion flanges is used. Only there, in the case of the orifice-plate installation, it is necessary to use welding neck flanges to allow the proper pressure connections to be made. If welded flanges are used, backing rings or weld projections should be removed before the joint is made up.

The design of the main steam piping in the rebuilt Conners Creek plant and that which will supply the new equipment being installed in the Delray plant of The Detroit Edison Company, has been influenced by the consideration of the steam-flow measurements in the initial design studies.

In these plants, provisions for three different classes of fluid-flow measurements have been made, based on the accuracy desired. For measuring feedwater quantities, meters have been provided which give an accuracy of something under plus or minus 1 per cent from 20 per cent to full flow. For this service, venturi-tube installations with diameter ratios of 0.50 have been used. Steam output from boilers is measured with flow nozzles having an accuracy of plus or minus 2 per cent from 20 to 100 per cent flow, while for turbine-steam consumption, flowmeters are used which have an accuracy of from 2 to 3 per cent plus or minus. The turbine flowmeters are installed primarily to give an indication of the load characteristics for operating guidance. The consideration given to the boiler and turbine flow-nozzle installations only will be discussed.

Studies made to determine the economical piping size of the Conners Creek boiler leads for 600-lb 825-F steam showed that 10-in. pipe would satisfy the over-all pressure-drop limitation. However, an investigation of the metering question disclosed that to use a nozzle with D_2/D_1 equal to from 0.70 to 0.75 would require the use of a secondary element capable of measuring a differential of 26 in. of mercury. With an increase in pipe size

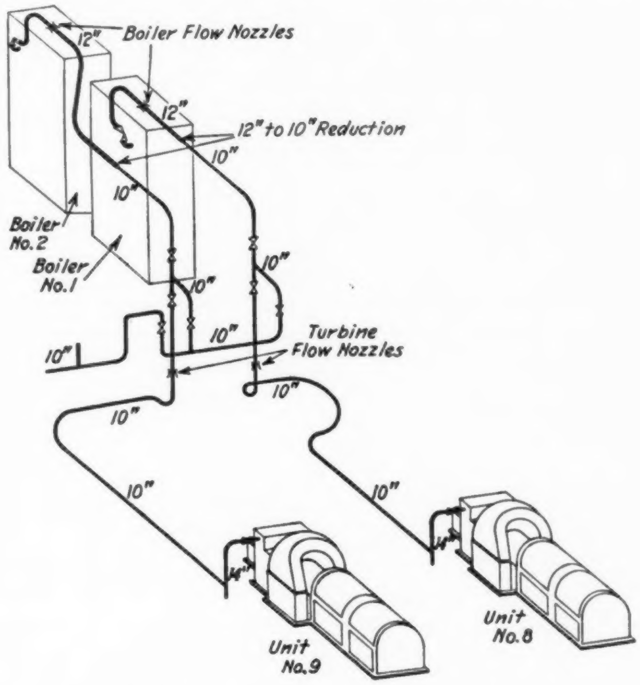

FIG. 2 ISOMETRIC SKETCH SHOWING LOCATIONS OF FLOW NOZZLES IN 600-LB 825-F STEAM PIPING OF CONNERS CREEK PLANT

to 12 in., it was possible to select a nozzle having D_2/D_1 equal to 0.755 which required a secondary element measuring only 16 in. of mercury. The cost differential resulting from the selection of 12-in. pipe instead of the 10-in. size was more than offset by the saving in cost of the secondary element. This saving for the first battery of two boilers amounted to approximately \$900. The extra cost of the 12-in. combination stop-and-check valve for the boiler above that of the 10-in. size was not included in this price comparison. The large valve size was used because of the materially lower pressure drop. For the maximum-flow condition of 433,000 lb of steam per hr, the velocity in ft per min was reduced from 16,900 for the 10-in. to 11,800 for the 12-in. pipe.

Fig. 2, an isometric sketch of the Conners Creek steam system, shows the location of the boiler flow nozzles. With the piping arrangement used, the securing of ample straight pipe before and after the nozzle was not a problem. In the case of boiler No. 1, the amount of straight pipe upstream from the nozzle was 15.1 diameters and downstream, 5.7 diameters.

Inasmuch as a less accurate meter installation was tolerable in the 10-in. turbine leads supplying steam to three 30,000-kw units, a nozzle having D_2/D_1 equal to 0.80 was selected which

allowed the use of the same secondary element required for the boiler flowmeters. Here the maximum velocity was 11,000 ft per min with a steam flow of 280,000 lb per hr. The lengths of straight pipe before and after the nozzles were 40 and 9 pipe diameters, respectively. Nozzles in the 16-in. steam leads to the 60,000-kw units were made with D_2/D_1 equal to 0.80. The maximum steam velocity was 10,700 ft per min. The secondary element was for the same differential head as in the other installations.

The selection of metering equipment for the 815-lb 900-F steam in the Delray plant resulted in the choice of almost identical nozzles and the same secondary elements used in the Conners Creek plant design. The economical size of piping for the boiler leads, based on a consideration of the allowable

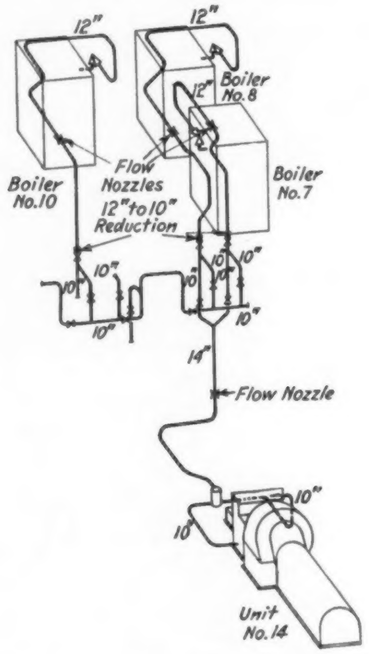

FIG. 3 ISOMETRIC SKETCH SHOWING LOCATIONS OF FLOW NOZZLES IN 815-LB 900-F STEAM PIPING OF DELRAY PLANT

pressure drop, was again 10 in. When the effect was considered of this pipe size on the nozzle and the secondary element required in order to use a nozzle diameter ratio with which reliable flow measurements could be obtained, 12-in. pipe was selected. In this case the savings made by selecting the secondary element for a lower head just offset the added cost of the 12-in. piping. The location of the nozzles for three boilers can be seen in Fig. 3. The nozzle-diameter ratio was 0.741. The increase in pipe size reduced the steam velocity from 13,500 to 9500 ft per min for maximum flow of 430,000 lb per hr.

The 14-in. steam lead to the 75,000-kw turbine was provided with a nozzle having D_2/D_1 equal to 0.815 and the intermediate-head secondary element. The upstream and downstream diameters of straight pipe for this nozzle installation and for the others discussed are given in Table 1.

The selection of the most concentric piece of pipe from the lot used for the line as the filler immediately preceding the primary element has been mentioned. This is a refinement in the erection of the piping system that perhaps may be difficult to justify from the accuracy gained in flow measurement but it is the practice of The Detroit Edison Company. The selected pipe sections also have been inspected for smoothness and longitudinal scoring. An analysis of the result of inside diametral measurements taken at the upstream pressure connection on a number of different fillers which preceded flow nozzles is given in Table 2.

TABLE 1 DIAMETERS OF STRAIGHT PIPE BEFORE AND AFTER FLOW NOZZLES

Service	Straight pipe diameters: Upstream, M	Straight pipe diameters: Downstream, N	Pipe size, in.	Remarks
Conners Creek plant:				
Boiler leads, odd nos..	15.1	5.7	12	Preceded by 8-ft-radius bend
Boiler leads, even nos.	26.8	5.7	12	Preceded by 8-ft-radius bend
Lead to 30-mw turbine	40.0	9.0	10	Preceded by valve and tee
Lead to 60-mw turbine	21	6.7	16	Preceded by 10 × 10 × 16-in. fitting
Delray plant:				
Boiler leads, odd nos..	26.4	14.2	12	Preceded by 4-ft-radius bend
Boiler leads, even nos.	59.2	11.6	12	Preceded by 60-degree offset
Lead to 75-mw turbine	19.8	8.3	14	Preceded by 10 × 10 × 14-in. fitting

TABLE 2 COMPARISON OF PIPE ECCENTRICITY FROM MEASUREMENTS AND FROM SPECIFICATION ALLOWANCE

Service	Pipe size, in.	Maximum actual variation from average measured ID, per cent	Maximum variation from nominal specification ID, per cent[a]
Boiler lead	12	0.12	0.82
Turbine lead	10	0.02	0.97
Turbine lead	16	0.20	0.75
Boiler lead	12	0.18	0.84
Boiler lead	12	0.09	0.84
Turbine lead	14	0.13	0.77

[a] A total tolerance variation of $^1/_8$ in., the sum of $+^3/_{32}$ and $-^1/_{32}$ in. from the nominal diameter, would increase the figures in this column over 0.25 per cent.

It is apparent that the allowable eccentricity is much greater than that obtained when careful consideration is given to selection of the pipe filler to be installed upstream from the primary element. While the maximum plus variation of $^3/_{32}$ in., allowed by specification and used in this comparison, is seldom realized, careful selection of pipe can reduce to a certain extent some of the inaccuracies always present in any metering setup.

In conclusion it might be well to summarize the various items that should receive attention in the initial stages of plant design to insure satisfactory and economical meter installations for the measurement of steam:

1 A suitable nozzle or orifice-plate diameter ratio should be selected to insure constant flow coefficients over the operating range of the meter if accuracies under plus or minus 2 per cent are to be realized. D_2/D_1 should not exceed 0.75 and preferably should be under 0.70.

2 The section of piping in which the primary element is installed should provide sufficient straight pipe upstream and downstream from the nozzle or orifice plate to eliminate swirls or eddies in the steam flow. If there is doubt as to whether undisturbed flow is obtained, straightening vanes should be used in addition to the minimum lengths of straight pipe.

3 The flowmeter manufacturers should be consulted before the final piping design is fixed to insure that the best installation is obtained.

4 The most concentric and smoothest pieces of pipe should be selected to precede the primary element.

Suggested New Definitions for

PROPORTIONAL LIMIT AND YIELD POINT

By L. H. DONNELL

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A COMPLETE description of the properties of an engineering material, for use in comparing the suitabilities of different materials for certain purposes or for designing intelligently for specific conditions, would involve an almost unlimited number of parameters. For practical purposes engineers have been forced to select a few of these parameters, which are sometimes somewhat indefinite and which certainly fail to give the whole story, but which have been found by experience to give at least an approximate picture of the most important properties of the materials.

Among the most useful of these parameters or indexes are the proportional or elastic[1] limit and the yield point. These quantities define the limiting stresses at which plasticity becomes important, and for the design of close-fitting machines and structures, or of slender parts which are subject to compression, they have largely displaced the ultimate stress as a measure of the useful strength of a material.

The proportional limit was originally defined as the stress at which plasticity or deviation from Hooke's law first appears; the yield point as the stress at which the stress-strain curve first becomes horizontal, that is the stress at which strain increases without increase of stress. These concepts were introduced at a time when strain-measuring methods were not very sensitive and structural iron or steel was the all-important material. We now know that the stress at which plasticity first appears is a most elusive quantity, depending perhaps entirely on the sensitivity of one's instruments, and at best involving the highly impractical determination of the point of tangency of a straight line with a curve whose curvature presumably starts at zero from this point of tangency. Furthermore, the new materials which have become so important in recent years do not have a true yield point according to this definition.

In spite of these difficulties the concept of a proportional limit as the stress at which plasticity first becomes great enough to be of engineering significance, and of a yield point as the stress at which plasticity becomes too great to be tolerated, or at which plastic flow starts to increase rapidly, have been too useful to be abandoned. Such indexes would be indispensable whether we used the old names for them or not.

The difficulty is in defining just how much plasticity is of engineering significance or is tolerable. Numerous attempts have nevertheless been made, and artificial proportional limits and yield points have been proposed and used which have been variously defined as the stress at which a certain percentage of plastic strain has occurred, the stress at which a certain percentage of total strain has occurred, or the stress at which the slope of the stress-strain curve is a certain percentage of the original slope E. The percentages chosen are necessarily quite arbitrary, and are usually selected to fit immediate needs, so that they may or may not be suitable as conditions change.

Several years ago the author proposed to Professor Timoshenko a somewhat new approach to this question, but at the time there were no experimental data available to illustrate the idea. Recently several papers have been published which supply the necessary data.

PROPOSED DEFINITIONS

If $\sigma_{\frac{1}{4}E}$ and $\sigma_{\frac{3}{4}E}$ represent the stresses at which the stress-strain slope is, respectively, $^1/_4$ and $^3/_4$ of the original slope E, the proposed proportional limit is defined as

$$\sigma_p' = 1.5\sigma_{\frac{3}{4}E} - 0.5\sigma_{\frac{1}{4}E} \qquad [1]$$

and the proposed yield point is defined as

$$\sigma_y' = 1.5\sigma_{\frac{1}{4}E} - 0.5\sigma_{\frac{3}{4}E} \qquad [2]$$

For a material such as structural steel, these formulas give values close to the proportional limit, as it is usually indicated by instruments of commercial sensitivity, and to the true yield point. For materials which have no true proportional limit or yield point the formulas define values which, interpreted according to the original understanding of these terms, give a picture of the stress-strain relations of the material in the early stages of yielding which is a close approximation to the actual stress-strain relations—probably as close an approximation as could be obtained with only two parameters.

Justification for these definitions can best be shown with the help of curves in which the stress is plotted against the slope of the stress-strain curve. Two papers[2,3] containing data plotted in this way have recently come to the author's attention. The changes which take place due to yielding are of course shown on the ordinary stress-strain chart, but these changes are tremendously magnified on the stress-slope chart.

Actual stress-slope curves for various materials are shown by the full lines in Figs. 1, 2, and 3. Fig. 1 is for a structural steel in tension.[3] This is typical of materials having both a definite elastic range and a true yield point. Fig. 2 shows curves for various aluminum alloys under tension and compression, both with and against the direction of rolling.[2,3] These curves are typical for materials which have definite elastic regions but do not have true yield points. Fig. 3 is for annealed copper in tension, which is typical of materials having neither a definite elastic range nor a true yield point.

Now the physical relation of stress and strain for any material in the range of elasticity and early yielding is obviously described by its stress-slope curve as a whole. We cannot expect to do more than describe the more important features of such a curve with a few parameters. The three parameters commonly used for this purpose, the proportional limit and yield point as usually defined, and the modulus of elasticity, are

[1] The slight differences between the proportional and elastic limits are beyond the scope of this discussion.

[2] "Variation of the Modulus of Elasticity of Duralumin," by W. L. Howland, *Journal of the Aeronautical Sciences*, vol. 4, October, 1937, pp. 507–509.

[3] "Column Strength of Various Aluminum Alloys," by R. L. Templin, R. G. Sturm, E. C. Hartmann, and M. Holt, Aluminum Research Laboratories, Pittsburgh, Pa., Technical Paper No. 1, 1938.

not necessarily the most suitable for this purpose, even for a material which has a true proportional limit and yield point.

For example, in Fig. 4, which shows one of the curves of Fig. 2, a knowledge of the true proportional limit σ_p would not tell us whether the stress-strain relation during early yielding follows the law given by the full line, or by the dash lines such as *a* and *b*. It seems evident that the difference between these three lines represents a difference in physical behavior which is of decided importance in relation to the strengths of short and medium-length struts and many other important engineering problems.

IDEALIZED CHART

A glance at Figs. 1, 2, and 3 suggests that all the stress-slope curves can be fairly closely approximated or idealized by two straight lines,[4] a vertical line representing the elastic stage (slope = E), and a diagonal line representing approximately the stage of early yielding. The dotted lines, in Figs. 1, 3, and 4 are such straight lines. The difference in physical behavior represented by the difference between the actual and the idealized curves would not be of great importance in most engineering cases. For example, calculations show that ultimate strengths of typical short struts, calculated from the full and the dotted lines in Fig. 4, would differ by only a fraction of a per cent.

[4] Suggested by R. G. Sturm in correspondence, October, 1933.

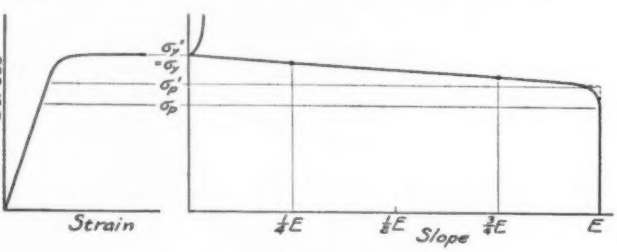

FIG. 1 STRUCTURAL STEEL IN TENSION

FIG. 2 ALUMINUM ALLOYS IN TENSION AND COMPRESSION

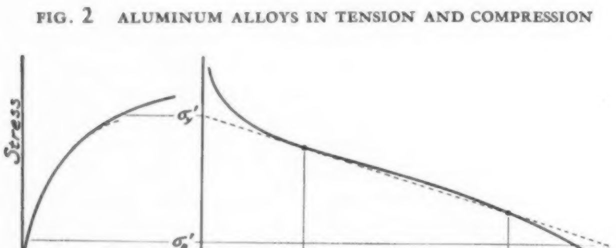

FIG. 3 ANNEALED COPPER IN TENSION

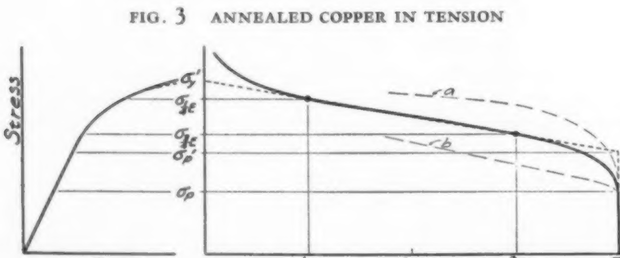

FIG. 4 TYPICAL STRESS-STRAIN AND STRESS-SLOPE CURVES

These two straight lines can be completely defined by three parameters. The usual modulus of elasticity defines the vertical line. The diagonal line can be conveniently defined by its intercepts with this vertical line and the stress axis (that is with the lines: slope = E and slope = 0).

These intercepts would evidently be the proportional limit and the yield point according to the original definition of these terms, for a material having the idealized stress-slope line. Even for the actual material they evidently represent, about as well as anything can, the stress at which plasticity begins to be of engineering significance and the stress at which it starts to increase rapidly. As they are also quantities which it is practical to determine even for materials with no real proportional limit or yield point, they seem to be the most logical quantities to use for an artificial proportional limit and yield point, σ_p' and σ_y'.

The method proposed for determining the diagonal straight line so as to approximate as closely as possible the actual stress-slope curve is merely to use the straight line passing through the two points on the actual curve corresponding to slopes of one fourth and three fourths of E. Formulas [1] and [2] then follow from simple geometrical considerations, evident from Fig. 4. It is true that the selection of these particular points is entirely arbitrary. It should be noted, however, that this selection is apparently not at all critical in determining σ_p' and σ_y'. All the curves are nearly straight in this region and it would make little difference if some other near-by points were chosen. The points suggested give a good approximation to the actual curves and simple formulas for σ_p' and σ_y'.

The stress-strain curves corresponding to the actual and to the idealized stress-slope lines are practically indistinguishable up to well above $\sigma_{\frac{1}{4}E}$ in all the cases studied. The proportional limits as they would be determined merely by inspecting the stress-strain curves are as close to σ_p' as could easily be measured. The true proportional limit is lower in all cases, but this somewhat indeterminate quantity is generally a less valuable index than σ_p', as the amount of yielding between it and σ_p' is entirely negligible for most engineering purposes. For the few cases where it is not negligible the true proportional limit should of course be used as an additional parameter.

The practical determination of $\sigma_{\frac{1}{4}E}$ or $\sigma_{\frac{3}{4}E}$ would be far easier than the determination of the true proportional limit, although more difficult with present-day apparatus than the determination of a stress corresponding to a certain percentage of strain. The work required to determine both a proportional limit and yield point probably would not be increased. If the proposed definitions should come into common use it seems likely that instruments could be developed for reading the slope directly, and these would be valuable also for determining that other most important parameter E, as well as in other ways.

While the proposed yield point is advocated as having a more significant physical meaning than other yield points based on arbitrary amounts of yielding, the values found for common materials under the proposed definition would not differ by large amounts from those given under previous definitions. Thus, for the twenty or so aluminum-alloy specimens described in the references the average value of σ_y' is within about 1 per cent of the average value of the yield point defined as the stress corresponding to 0.2 per cent plastic strain. Individual values differ by from 1 to 8 per cent.

ENGINEERING'S PART *in the* DEVELOPMENT *of* CIVILIZATION

V—The Inseparability of Engineering and Civilization

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ARE WE seriously thoughtful of our responsibilities to civilization; and also can we be properly lighthearted and optimistic regarding human affairs?

Lightheartedness regarding any circumstance may arise out of ignorance which prevents foreseeing possibilities of false steps and even of failure. Such is a false lightheartedness. Sound and true lightheartedness arises from courage coupled with a knowledge through which the difficulties and pitfalls in the course of progress are foreseen and can be guarded against, and the joys of achievement can be visualized. It is this sound and true lightheartedness regarding the progress of civilization that is commendable. In order that we may rightly hold this doctrine, it is important for us fully to understand the inseparability of those two human developments respectively called engineering and civilization as this inseparability is indicated in the preceding lectures.

Before proceeding on our way in the discussion of this relation it is desirable to review our bench marks in an engineer's habitual manner, and I will recall to your minds the definitions of the words *engineering* and *civilization*.

Engineering is a process of planning, organizing, and executing work concerned with directing the forces of nature for the service of man. It includes the important problems relating to transportation by land, water, and air, recovery and processing of mineral products, river control, irrigation, drainage, water supply and sewerage, artificial illumination, mechanical and electrical power, machinery, manufacturing practice, electrical communications, stationary structures of numerous characters, and indeed other features, present and prospective, which relate to man's food, clothing, shelter, and affairs of daily concern arising from his community of purposes in association with his fellows.

The qualities connoted by the word civilization are developed from the sense of mutuality of interests which arises in and between integrated groups of people living in peace and amity. These qualities blossom to their fullest degree as firmer integration of communities follows in the wake of the great physical inventions which increase the comfort, convenience, and leisure of men above the conditions of a bare-subsistence life. That is, the word civilization connotes an advanced state of material and social well-being, and well-established ethical and moral relationships, among men. In an earlier lecture I quoted Breasted's statement of civilization's growth out of community life. The late George F. Moore, distinguished professor of history of religion, has expressed the situation in the following manner:

> Civilization develops only where considerable numbers of men work together for common ends. Such unity is brought about, not so much by community of bare ideas as by community of the feelings by which ideas are emotionalized and become beliefs and motives. The unifying, like the divisive, forces of civilization may thus be described as psychological. The history of civilizations has been written from various points of view—political, geographical and climatic, economic—but while these factors are not to be ignored or underestimated, they are conditions and circumstances which may explain peculiarities of particular civilizations, or their rise and fall, but do not account for civilization itself.

The quotations in this tone which could be cited from authoritative scholars in various branches of learning are innumerable; but I will rest with these two, of which one is from a noted archaeologist and the other from a noted scholar in the history of religion.

Emerson in the middle of the nineteenth century said in one of his odes:

> Things are in the saddle
> And ride mankind.

But Emerson was of a philosophic temperament, possessing little cosmopolitanism. The best thought of man refuses to assume that Providence has sent "things" into the world booted and spurred to ride mankind and that millions of men are saddled and bridled and ready to be ridden.

We apparently must admit the inherited stupidity of human beings. That stupidity is evidenced by the creeping slowness with which prehistoric men improved their means of livelihood when opportunities for improvement lay all around them awaiting to be observed. It is equally evidenced by the primitive men and nomads of the present day. Sven Hedin in the desert of Sinkiang asked of an old native how far the desert reached to the north, from the point where the river they had seen disappeared in the sand. The answer came, "To the end of the world; and it takes three months to get there." Again, it is evidenced by our own failure to gain the most for ourselves and our fellow men from the opportunities for comfort, peace, and happiness which the foundations of our present-day circumstances would permit. However, taking history decade by decade as well as century by century the record is one of betterment.

Associated with his translation of the ancient Chinese religious book called "The Way and Its Power," Professor Waley comments, "People of the tenth century B.C. would assuredly have been at a complete loss to understand what Mencius (in the second half of the third century B.C.) meant by his passionate and moving plea for the theory that 'man is by nature good.'" There was a glimmering of the meaning understood by the people by the date when Mencius spoke in the third century B.C. In this, our day, twenty-two centuries after Mencius, it is probable that people in general understand the ideals that moved Mencius' thought, although many may reject his sentiment. If this is true, it

Fifth of a series of six lectures on this subject delivered at the University of North Carolina State College of Agriculture and Engineering, Raleigh, N. C., Jan. 21–29, 1938.

shows a gradual but exceedingly slow improvement of social sense. This also indicates that the professional sociologists have not been very successful in their efforts to lead us out of the sociological wilderness, and we must look farther for a guide (a Joshua) to take us into the Promised Land.

Some decades ago the historian Taine, in his "History of English Literature," pointed out that on the eve of the nineteenth century the thinking people and the human attitude had changed through the influence of engineering works like the steam engine and steam transportation, and "comfort, leisure, education and many of the other amenities that grace modern society became the heritage of the common man instead of the privileges of the few." And change still goes slowly marching on.

Those social leaders who are uncomplimentary enough to say or think that the people of today cannot understand the reasons for political movements, when the reasons are clearly set before them with some reiteration, fail in their recognition of the effects of modern education and of intimate personal and community interrelations. The minds of such leaders are in the period of 2500 years ago. Confucius, over 2400 years ago, said that "the people may be made to follow a course but not to understand the reason why." But educational processes and mutual interrelations have greatly altered the situation since he made the statement. The alteration has been particularly notable in the western nations and others in which internal education and external contacts have been both assiduously cultivated; but it is a fortunate fact that any great people still takes a long time to become fully convinced regarding the reasons for political movements and their relative desirabilities, as such deliberateness prevents us from falling into some of the mistakes toward which professional reformers naively urge us.

It is true that the influence of scholarly circles on progress in the comfort of living, and on progress in the ethical ideas, of the masses of mankind takes hold only slowly. This condition exists because the thinking of scholars is not understood and digested by the masses of mankind, even if the scholars' thinking chances to be directed toward general betterment. The mode of progress in comfortable and ethical living is determined by what the masses of mankind think out more or less for themselves from what they believe they know as a consequence of their own experience. The more the social organization improves, the more it is clear that human nature remains substantially the same and is easily stampeded by demagogism. But, successful, stable improvements of mutual relations cannot be rushed by the vaguely applied efforts of professional reformers or dilettantes. Such improvements may only be produced slowly in association with sounder growing mass thought regarding living affairs in both material and ethical relationships. This seems to be the condition of affairs all over the world. The likeness of this condition all over the world is expressed in the Spanish proverb that "everywhere in the world they cook beans."

People of various experiences and weights of influence have been joined together in asserting again and again, with such emphasis and frequency that it has come to be generally believed, that this is an age of greater complexity in human affairs than has existed ever before. This is a doctrine which seems to be supported by many of the details of life, but it does not bear critical analysis in fundamental aspects. In this age, the full analyses show that certain of those phenomena (or relationships) which are dubbed complex have in fact contributed to clarifying living conditions. They have, indeed, widened the group on whom falls a responsibility for the lives of themselves and their associates, thus carrying responsibility for community affairs to a greater number of human beings; but that is a different phenomenon from an aggregate increase of complexity in living.

In feudal times, the serf either lived a sordid and hard life or died of hardship and starvation, depending on the efficiency and attentiveness to supervision characterizing his master; and the children of the serf followed in the way of their father. That was simplicity applied in the simplest degree for the serf, but the lord of the manor, or his equivalent, bore on his shoulders the complex affairs in heavy degree while he shifted the hardships due to poverty on to his retainers as far as was possible. Modern western ethics will not tolerate such conditions. The result is that responsibility for conditions of living is widely spread over the population with the consequence that more individuals take up the load and there is a more widely distributed wish to understand the conditions which are necessary for security in livelihood and happiness. Thus the complex affairs of life are spread over the shoulders of most of the population and more individuals feel them, in those locations where liberty-loving democracy is established.

It is also true that human beings now have wider touch with each other, either through actual contact as of old or through the added rapid intercommunication by wire and space; but people also have greater control over their own affairs because they now are more generally independent of intrenched tyranny, or tyrannical feudalism, and they, moreover, can fend more effectually against the impersonal cruelties of nature. Straightforward, analytical thinking, supplemented by synthesis, now moderately characterizes even the commonplace and least educated among westerners, which enlivens life and aids in softening its physical asperities compared with former centuries when superstition or false religious tenets controlled human relations. Lifting the mind to observe what is around and about it, and applying the observations synthetically to the affairs of life, is not oppressive or complex in contrast with relying mostly on individual superstitious deductions or on the tyrannical commands of feudal chiefs and religious cults, although it proves disturbing to some sensitive individuals who are unable immediately to provide means for aiding the less fortunate who are near them.

One of the difficulties of our times arises from the fact that the luxuries of a few years ago are now viewed as necessities. I do not visualize the numerous new opportunities for pleasing use of leisure as adding to the complexity of life, although they lay on each individual a responsibility for using his leisure wisely. Leisure has increased in the civilized world, during the last century, and continues to increase; and this produces a problem in education for fitting choice of recreational activities. The addition to actual leisure which we now enjoy, because of labor-saving machines, has indeed imposed on us a new and as yet unsolved problem, namely, to secure for everyone of thrift and industry opportunity to earn sufficient compensation for his work so that he may truly enjoy his leisure.

We have seen from what I have laid before you in previous lectures that community relations, from which the just-described improved outlook arises, are the consequence of living conditions wrought out by engineering thought and effort. The earliest men may have tended toward separation from each other in efforts to secure food and, in general, to maintain life; or perhaps they tended to hold together in only small groups. When engineering thought thereafter produced the essential ideas for community projects, food finding was aided, as also were the means for providing for shelter, and for protection from attacking enemies whether of stranger-men or of wild beasts. Original trends toward community life therefore may be seen to be utilitarian. True gregariousness which arises from mutual sympathy and interest with other persons is an

. . . . as late as the seventeenth century . . . . the inhabitants of rural villages in Great Britain, which then were isolated from broader contacts on account of the frightful condition and the meagerness of the roads for travel, viewed every stranger with alarm . . . .

(From Smiles's "Lives of the Engineers")

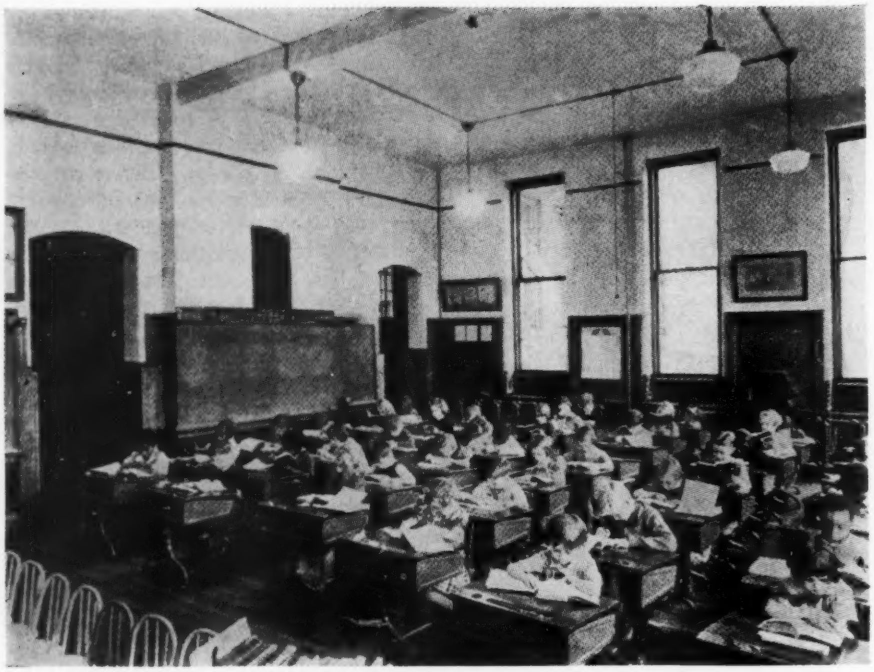
intellectual development that comes later than the mental craving for security of food, clothing, shelter, and life itself. This true gregariousness, however, is a quality that is fostered by living conditions which offer fair assurance of adequate food supply, clothing, shelter, and safety of life. It therefore follows in the wake of enlarging engineering activities and works.

Even the extent of the command of language and its expansion and refinement in use depend to a large degree upon the size and mutual sympathies of communities, and therefore these phenomena are activated by the consequences of engineering works which make community life practicable. However, early communities were in little contact with each other and inhabitants of any one were strangers to the inhabitants of any other and therefore under suspicion of being enemies unless provided with convincing introductions and credentials. It is said that, even as late as the seventeenth century of our era, the inhabitants of rural villages in Great Britain, which then were isolated from broader contacts on account of the frightful condition and the meagerness of the roads for travel, viewed every stranger with alarm and were impelled to drive him from the community area.

As the primitive communities became individually integrated, certain conditions forced themselves into recognition which led to the formal or tacit formulation of rules for mutual conduct of the inhabitants. Lawfulness and friendliness then became not only an objective, but more or less a fact in such village communities. Ethical principles and moral acts became part of the community spirit. Purely selfish utilitarianism gradually gave way for the admission of life elements which included sympathetic relations with fellow citizens. But lack of physical means for easy communication between separated communities caused continuation of suspicion and emnity between the communities, that only faded in intensity as engineering achievements made communication practicable and easy and illuminated the advantages of a broader mutuality and cooperation. Therefore, civilization grew slowly, beginning in a vague way in prehistory, but having begun, it continued to grow under the influence of steadily enlarging engineering activities which produced new contacts and made old contacts more intimate between individuals and individuals, individuals and groups or communities, and between communities and communities.

The situation is summed up rather interestingly by L. T. Hobhouse, a British sociologist, as follows: "Morality at its outset is bound up with the structure of the social group. Between members of any one community the obligations recognized may be many and stringent, while in relation to outsiders no obligations are recognized at all." Each early community, brought together through its own engineering improvements, was an isolated people who were mutually friendly among themselves, but in the isolation, caused by almost insurmountable barriers to wider communication, the people dreamed of the inhabitants of other such communities as enemies toward whom no ethical or moral obligations existed. Engineering progress in communication was the requisite for widening the horizon of civilization to such peoples. As L. T. Hobhouse again puts it, "ethically as well as physically, humanity is becoming one . . . . . . by a widened consciousness of obligation, a more sensitive response to the claims of justice, a greater forbearance towards differences of types, a more enlightened conception of human purpose;" which results, I may add, are the consequence of the wider contacts and intimacies brought about by the effect of readier communication, especially of travel, within and between communities. By living in ready contact with each other, we have come to recognize, in at least a glimmering degree, that the best living is when the life is put to intelligent use in mutual advantage. This involves neither "to live dangerously," as supported by Nietsche, nor to live too guardedly. We yet have much to learn before we can set the particular path that it is most desirable to pursue while avoiding the two extremes; but ultimately we shall be able to mold our engineering so as to achieve the wished-for ends.

Let us now sum up the situation. If my memory holds correctly, it was Thomas Carlyle who, as a philosopher, held that man is unique as being the tool-using animal. Perhaps the conformation of the hands of man brought that tool using to pass; and the effort applied toward tool using may have had a part in molding that conformation. In any event, the artifacts and remains left to us from prehistorical times, carefully studied and interpreted by archaeologists, show that in his earliest life man started making crude tools and other implements out of materials available. If made of easily perishable material, the remains, exposed to the vicissitudes of geological and weather changes, might not have come down to us through a period of thousands of years; but enough made of imperishable and other materials have come down to us to inform us indisputably that man began in crude artisanship, which he continued to improve by chance or by cut-and-try methods



. . . . developing powers of observation added to practice of physical invention resulted in engineered villages and their community life, coupled with customs of living such as are required for secure life when people are in close mutual contact. (Child labor gives way to mass education.)

(From Transactions of the Illuminating Engineering Society, October, 1937, p. 94)

over a long period of time. In that long period, the gregarious spirit had not arisen among men. They tended to keep apart as individuals or in small groups. This was not a state of civilization. Problems of ethics and morals were not then features of living, as they afterward became with the development of communities.

Then began the era of bringing the elements that might be produced by artisanship together into such combinations that new and serviceable results were obtained as a consequence of the combining. That began the era of engineering invention. This era required increasing intellectual effort from those taking a part in the new achievements, but the desire for release from muscular burdens in guarding life and securing livelihood was an impelling cause for active-minded men to make the effort. The developing powers of observation added to practice of physical invention resulted in engineered villages and their community life, coupled with customs of living such as are required for secure life when people are in close mutual contacts. Customs of living became formulated into ethical principles and specific moral codes to guide the practices of life; artisanship and agricultural cultivation intensified; trade germinated; the building of rafts, boats, and ships sprang up; and trading was extended to great distances. It took active-minded men to do these things. Stale minds do not produce greatness in the designs of ships or machines or structures or engineering enterprises, any more than they produce greatness in the production of poetry. Active-minded men have influence on others with whom they come in contact; and trading expeditions carried along the community customs of the enterprising traders and implanted them over the trading area.

Thus civilization arose through the development of community life, and was spread abroad by contacts of traders and travelers. Engineering projects and equipment provided the seeds for its rise and its dissemination. No less truly has the further development of engineering fertilized the growth and wider spread of civilization. The two have been and are inseparable. In the words of the United States Supreme Court Justice Holmes, "the best test of truth is the power of the thought to get itself accepted in the competion of the market." I hope that full reflection will bring you to an unreserved recognition of the truth of this important thought of the inseparability of engineering and civilization.

When we analyze the present state of civilization, we must confess that it is disappointing, and much refreshment is needed, in both small and large aspects. The adjustment of social institutions lags behind the progress of social opinions, and equilibrium between the two is always in course of rectification. This always will be the case, short of a mythical millenium; but the lag can be reduced and emphasis should be placed on a comprehensive effort to produce this reduction.

The permanent influence of any individual on the social organism depends upon the soundness, i.e., the ethical rightness or else the expediency of his views, and upon the steadfastness of his purpose and his expression of the purpose; but every critical examination of the minds, as expressed by their acts, of individuals, communities, and nations discloses how overwhelmingly the spirit of adventure guides human beings into opportunism and into becoming followers of expediency, in contrast with treading the definite path of ethical rightness. This may be the consequence of defects in education. Emerson says in his essay on Politics, "We think our civilization near its meridian, but we are yet only at the cock-crowing and the morning star." In any event, as the Chinese say, "True wisdom is different from great learning."

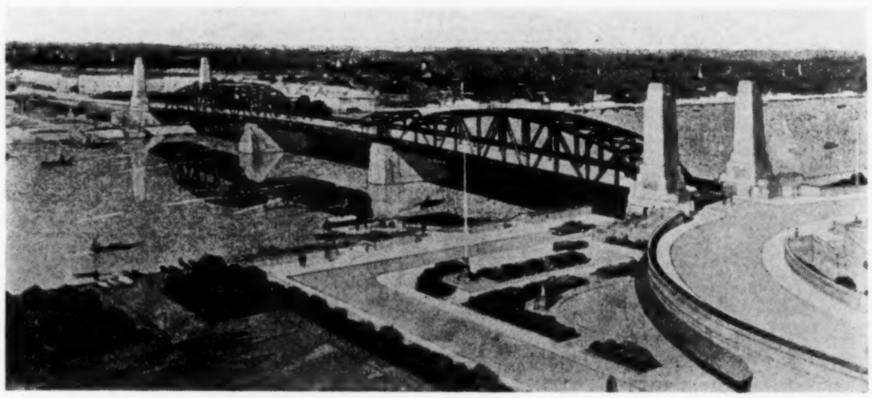
A transcendent question to be answered by the social reformers is: If we sin through ignorance, can we become virtuous through wisdom, and, if so, how? Apparently the mutual relations arising as a consequence of engineering developments have not yet become complete enough to confirm a full sense of tolerant consideration between people as individuals and also between peoples as nations. The recital of man's development shows that the mind of man moves slowly and his intellectual habits possess great inertia. Therefore, the gap observable between the possibilities of and the results secured from civilization may not be wholly erasable, but experience justifies the hopeful belief that it can be brought to minor limits.

As we have spent considerable time in these lectures examining the source of civilization as an outcome of engineering works, it is now appropriate to examine into what stimulating reaction on the farther development of engineering may arise from any step in the growth of civilization. As a matter of fact, in all physical affairs, where two phenomena are in such contact that one acts upon the other, there arise both action and reaction. A somewhat similar situation may associate with social phenomena. At any rate, there is no gainsaying that each step forward in civilization has opened new vistas to creative minds, additional discoveries and inventions in physical affairs have occurred, and additional release from muscular

labor and additional opportunities for mutual contacts between human beings have been achieved. Thus, not only is civilization dependent on engineering for its origination and development; but, also, the concomitant growth of civilization stimulates additional steps forward in engineering and again proves the inseparability of the two.

There shines a glorious world in the dreams of creative discoverers and inventors in the field of engineering, because those creative dreamers know that civilization and the friendliness of man step forward as the scope of engineering widens. Creative science requires for its devotees keen powers of observation and fertility in inferences. Add to those qualities the further qualities of initiative, resourcefulness, courage, and (for engineers) a full sense of human relations, and the man may become either a great engineer or a great research scientist according to his tastes. Such men are prime agents for the further development of civilization. The process of engineering now has come to depend deeply on the expansion of knowledge in science in order that the engineers may possess the opportunity to make additional useful applications. Engineers therefore stand hand-in-hand with scientists for the sake of engineering and civilization.

Some men, who have not learned that ice and embers cannot lie in the same bowl, disregard the advantages which they may securely possess from the fruits of engineering, and, as of old, they abuse their opportunities, for example, by waging destructive war for selfish reasons, imposing "rackets" on the public, or imposing sweat-shop or serf-like conditions on labor. In reference to such acts, condemnation should not be aimed at engineering. Outspoken, and general, public condemnation should be aimed at the fountainhead of fault, namely, at the delinquent measures of those men who have not yet grasped the high significance to themselves and the world of an ultimately complete civilization. Able professional sociologists in this nation can do a great practical service if they will further enlarge upon the arguments which show the disservice of existing abuses, and on the basis of the arguments lead the expression of public condemnation. While it is aside from the topic of this lecture, I venture to suggest that such procedure is, for the sociologists, a part of individual and group responsibility to civilization which as yet they have not seriously embraced.



. . . . the gap observable between the possibilities and the results secured from civilization . . . . (Statue of God at Bangkok, Siam; and a modern Siamese bridge, leading to an ancient temple.)

(Bridge from "The Engineer," vol. 154, p. 248)

The favorable material influence of engineering on human well-being has progressed slowly, step by step, as the intelligence of man has become enlarged by experience; and the rate of acceptable achievement has accelerated as intelligence enlarged. At the same time, mutual contacts have been increased, a sense of mutuality of interests has established itself, and the desirability of amity and fair-dealing in personal and community relations has illuminatingly shown itself; which phenomena are also functions of man's intelligence. Thus, both components of civilization, the material and the ethical, expand in serviceability as intelligence expands. Democratic legislation, dictatorial proclamation, and tyrannical ukase are alike incompetent to increase the rate of expansion of these components beyond the rate of growth of intelligence. On the other hand, to restrain the growth of engineering, which has been urged by some in the mistaken belief that it would afford opportunity to favorably adjust social conditions, would merely retard the growing opportunities for material welfare. Continued active cultivation of science and engineering is at the foundation of our good hope for continued betterment of civilization.

A good hope is better than a bad possession, says Sancho Panza. For the possession and hope both to be good is better yet, say I. Although we must acknowledge that it is easier to be wise for others than for ourselves, it is nevertheless necessary for these lectures to sum up our present relations with civilization and engineering; and, stirred with curiosity and ambitious anticipations, to strain our eyes into the future for the purpose of endeavoring to see the progress of future events. Such will be the objectives of the next and concluding lecture.

SOME CHALLENGING TAX QUESTIONS

By FLOYD E. ARMSTRONG

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THE HODGEPODGE of taxation methods that is the American system has been once more critically examined and appraised by a Committee on Taxation of Twentieth Century Fund Inc., and the analysis with the Committee's recommendations has appeared under the title "Facing the Tax Problem."[1] The larger part of this book consists of a careful and complete statement of the existing system and an appraisal of its success in meeting the aims and objectives that are sought. The concluding and much more stimulating and challenging part carries the recommendations of the directors of the research in proposals for change.

The aims of taxation fall into two groups—primary and secondary. The primary aims are broadly speaking two: (1) The raising of revenue, and (2) social control. The secondary aims are also two: (1) Simplicity in administration and (2) an adjustment of the tax burden to each individual's ability to pay. Few if any will take issue with the first primary objective, except to insist that the revenue to be raised shall not exceed the "taxable capacity" of the nation. Many there are who will challenge the propriety (even the legality) of using the machinery of taxation as an agency for positive social control. There are, it is true, many examples in our history of the use of taxes either to encourage certain industries (protective tariffs for instance) or to discourage certain types of consumption considered socially dangerous—for example, the consumption of liquor. Such tariffs and taxes are usually defended on the ground that their social purposes are merely incidental to the more primary purpose of raising revenue. Now, however, comes a whole flock of new taxes, enacted with the avowed purpose of social control—some at least in areas where constitutional authority for such control might be otherwise lacking.

TAXATION FOR SOCIAL CONTROL

Taxation for social control may appear in at least three ways:

1 It may serve to effect a secondary distribution of wealth and income, to correct and offset an inequitable apportionment as produced by the economic system. Graduated income taxes and inheritance and estate taxes as they apply to the largest incomes and estates are clearly of this sort. Quite definite limitations exist in the application of this principle, however, if private capitalism is to continue. It is certainly true that income that does not exist cannot be distributed and it follows that a practical limitation appears when the incentive for private effort has been destroyed. It is also apparent that a redistribution of accumulated wealth through the agency of taxation necessitates conversion of physical wealth into cash money. To accomplish such a conversion means either sale for cash (an impossibility on any large scale because of the limited money supply available at any given time and place) or enormous bank borrowings whenever the attempt is made. The latter procedure must result in rising prices and falling real incomes with the accompanying disturbances to the national economy.

2 A second way in which taxation for social control appears is in financing subsidies to encourage and control private activities. Prominent among such are ship subsidies and payment to farmers to induce restriction of crops. Extensive use of taxation in this manner appeared to be under way during the early years of the Roosevelt administration, but important judicial pronouncements have, at least for a time, checked the movement. In the Agricultural Adjustment Act decision the Supreme Court ruled that the federal government has no authority to regulate agriculture. Processing taxes for the purpose of such regulation were declared unconstitutional. In the same decision the Court ruled that a tax is invalid if it is levied to finance a control that the federal government has no power to exercise. If this ruling is sustained in future decisions, a threat of very far-reaching importance will have been removed.

3 Finally, taxation may be used to capture, for the benefit of all, those socially undesirable gains enjoyed by certain individuals. Excess-profits taxes fall within this category and are levied as an application of the doctrine that profits beyond a certain point are prima-facie evidence of unjust prices. It is difficult to reconcile this doctrine with orthodox economic ideas, but it has been rather generally adopted and seems to be in harmony with the law. Land increment taxes, the special item of attack by single taxers, have been occasionally used in this connection.

Analyzing the American tax system as it has actually developed, has led the authors to certain rather definite conclusions—some at least of which are open to argument. For example, they express the belief that the amounts now raised by taxation and the amounts likely to be demanded in the near future are not beyond the economic limits of our taxable capacity, in the sense that they will not so stifle business initiative and saving as to threaten the private capitalistic form of enterprise. Such a conclusion obviously carries only the weight of the opinion of the one expressing it. There are so many uncertainties ahead that one must be hesitant in accepting this comforting thought. One conclusion which will be widely approved is that the existing tax system is too heavily weighted against risk-taking forms of enterprise. Both the federal income tax and most state income taxes claim so large a share of the winnings from such endeavors, if made, that they dissuade venture capital from taking the risk of loss that is always present. The result is a throttling of the initiative on which alone we must depend for relief of our unemployment burden. The thorny question of taxing undistributed corporate surplus is handled in a broad and understanding way—too extensive for detailed discussion in this review but well worth study. Admitting the undesirable features of the undistributed-profits tax act that was so hastily passed (now largely removed by later amendment) and disclaiming any belief in the wisdom of attempting to force the judgment of directors in the matter of handing out cash to stockholders, the committee concludes that the proposal has promise, if properly used, in integrating corporation and individual income

(*Continued on page 851*)

[1] "Facing the Tax Problem," by Thomas I. Parkinson, et al., Twentieth Century Fund Inc., 1937.

One of a series of reviews of current economic literature affecting engineering prepared by members of the department of economics and social science, Massachusetts Institute of Technology, at the request of the Management Division of The American Society of Mechanical Engineers. Opinions expressed are those of the reviewer.

Possibilities for UTILIZATION *of* PULVERIZED-COAL ASH

By A. W. THORSON and JOHN S. NELLES

THE DETROIT EDISON COMPANY, DETROIT, MICH.

THE DISPOSAL of fly ash collected from pulverized-coal-fired boilers is a problem of general concern to the central-station industry.[1] The increasing capacity of these units in operation and the use of dust-collecting devices are multiplying the quantity of fly ash collected. The use of the slag-bottom furnace somewhat reduces the percentage of coal ash going to the stack, but in most of such installations there still remains a fly-ash-disposal problem. Dumping it on waste ground for fill is not a permanent solution, for adjacent land is usually limited, and furthermore, its load-bearing ability is impaired by the deposit of fly ash.

For the past ten years The Detroit Edison Company has been seeking a market for the quantity disposal of fly ash collected at its Trenton Channel Power House. Early in the investigation it was determined that this market must be a local one, and that the building-materials industry appeared to be the most attractive. Subsequent work has therefore been concentrated in this direction.

The most promising results from the standpoint of quantity disposal have been achieved (*a*) in Cottrell block, where fly ash constitutes 90 per cent of the dry mix; (*b*) in fly-ash-cinder concrete, completely replacing sand; (*c*) in pebble concrete as an admixture, replacing up to 20 per cent of the Portland cement; and (*d*) in asphalt paving, as a filler.

For use in concrete, fly ash should contain not more than 13 per cent of material retained on a 200-mesh sieve and should contain not more than 7 per cent carbon.

Continuous disposal may not be provided by the building industry because of its dependence on the seasons and the business cycle. However, Cottrell block, and the fly ash itself when dampened, can be stored if necessary.

Table 1 gives the properties of Detroit fly ash and handling costs, the remainder of the paper gives an account of the various projects investigated. Many of these have been abandoned because of local conditions, but are included in the hope of suggesting a market in other localities. This portion of the paper is summarized in Table 2.

The investigation covered use of fly ash as an inert filler, an aggregate and admixture in concrete products, an abrasive, and in several miscellaneous products.

FLY ASH AS A FILLER

Fly ash was used as a filler in asphalt paving materials, fertilizer, rubber, primer paint, putty, roofing material, common brick, and cinder block.

Sheet Asphalt. In the laboratory it was found that a mixture of Detroit sand 84.5; Detroit fly ash 6.0; and asphalt cement 9.5, in per cent by weight, would produce a paving material of satisfactory workability, compressibility, and stability. Not over 8 per cent ash should be used in any case.

[1] See Bibliography (1, 3, 4, 5, and 9).

Contributed by the Fuels Division for presentation at the Annual Meeting of The American Society of Mechanical Engineers, December 5–9, 1938, New York, N. Y.

Fig. 1 shows the comparative percentage of voids in fly ash and limestone dust. Pound for pound, fly ash is a more effective void-filling agent because of its greater fineness and lower density, but has a lower asphalt-carrying capacity.

Results of stability tests are shown in Fig. 2. Values between 2000 and 3000 are considered desirable for heavy traffic. However, the best stability value obtained with fly ash occurred when the asphalt content was 7 per cent which is too low for northern localities.

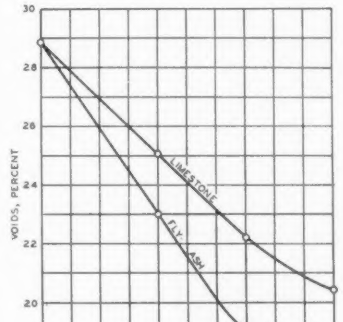

FIG. 1 COMPARISON OF VOIDS IN MINERAL AGGREGATE USING LIMESTONE AND FLY ASH AS A FILLER

TABLE 1 TRENTON CHANNEL FLY ASH

Chemical analysis	Per cent by weight
Aluminum, Al_2O_3	29.3
Iron oxide, Fe_2O_3	11.7
Silica, SiO_2	46.9
Magnesia, MgO	0.9
Lime, CaO	2.6
Carbon, C	6.5
Titanium oxides, TiO_2	1.3
Unclassified by difference	0.8
Total	100.0

Sieve analysis	Cumulative percentage by weight
Retained on 50-mesh	1.2
Retained on 100-mesh	4.6
Retained on 200-mesh	12.9
Retained on 325-mesh	53.9
Through 325-mesh	46.1
Total	100.0

Handling method	Cost, dollars per ton
In bags:	
Cost of bags	1.14
Labor	0.11
	1.25
In bulk (box car):	
Labor for paper lining and loading	0.20
In bulk (gondola), damp ash containing 18 to 25 per cent moisture:	
Labor for loading	0.15

Several sections of paving using the fly ash have been laid in

TABLE 2 SUMMARY OF INVESTIGATION—POSSIBLE USES FOR FLY ASH

Product	Use	Material replaced	Cost of material replaced, \$ per ton	Type of investigation[a]	Extent of investigation[b]	Results[c]	Remarks
1 Sheet asphalt	Filler	Limestone or silica dust	3.00	L & F	T	E	Local plants unsuited to fine material
2 Sheet asphalt	Filler	Portland cement	7.50	F	T	E	Small quantity used
3 Fertilizer	Filler	Foundry sand	Cartage	L	P	..	Replaced material too cheap
4 Rubber	Filler	Fuller's earth	8.00–12.00	P	P	P	Too coarse and gritty
5 Primer paint	Filler	Calcium carbonate	20.00	L & P	P	G	Small local market
6 Putty	Filler	Calcium carbonate	20.00	L	P	G	Small local market
7 Roofing material	Filler	Limestone or silica dust	3.00	..	..	..	No local market
8 Common brick	Filler	Clay	0.25–0.50	P	T	P	Weak structure
9 Cinder block	Filler	....	......	P	T	G	Waterproofs surface
10 Sand-lime brick	Aggregate	Sand	0.75	P	T	P	Equipment unsuited to fine material
11 Aerocrete	Aggregate	Sand	0.75	L	P	P	Poor concrete; small market
12 Lightweight concrete tile	Aggregate	Sand	0.75	P	T	P	Machine not commercially available
13 Acoustic plaster	Aggregate	Pumice	20.00	..	P	P	Color objectionable; application more important than material
14 Haydite concrete	Aggregate	Haydite	8.00	L & P	T	G	Expensive product; small market
15 Cottrell block	Aggregate & binder	Pulverized shale	......	L & P	T	E	Active project
16 Sodium-silicate block	Aggregate	....	......	L	T	P	Expensive and unsatisfactory
17 Pebble concrete	Admixture	Portland cement	7.50	L	T	G	Reduced heat of hydration
18 Portland cement	Raw material	Clay	0.25–0.50	L & P	T	G	Raised coal consumption
19 Brick	Dusting	Sand	0.75	P	T	P	Stuck in molds
20 Petroleum	Color filter	Fuller's earth	8.00–12.00	L	P	P	Small market
21 Foundry	Dusting and sand	Sand	0.75	P	T	P	Small market
22 Metal	Polisher	Pumice	20.00	L	P	P	Not abrasive enough
23 Cinder concrete	Sintered aggregate	Cinders	......	L	T	G	Too expensive
24 Fly-ash cinder concrete	Aggregate	Sand	0.75	L & F	T	E	Active project
25 Sand blasting	Condenser tubes and turbine blades	Sand	0.75	P	..	E	Gives high polish and low metal loss

[a] F = field, L = laboratory, P = plant. [b] P = preliminary, T = thorough. [c] E = excellent, G = good, P = poor.

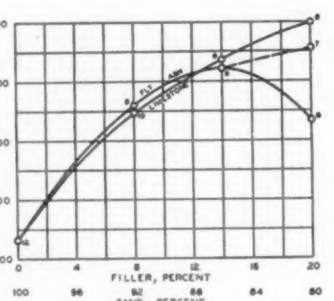

FIG. 2 COMPARATIVE STABILITY OF ASPHALT PAVING MIXTURES USING LIMESTONE AND FLY ASH AS A FILLER

(Figures at plotted points indicate percentage of asphalt cement used in the mix.)

Detroit. The first, about 1200 sq yd, was made on a heavily traveled street several years ago. No evidence of cracking, rutting, or effect of freezing and thawing has thus far been observed.

Substitution of fly ash in sheet asphalt replaces a material costing about \$3 per ton. In normal years, about 60 tons per day for 200 days per year could be disposed of.

This project failed in Detroit because the asphalt-plant equipment was unsuited to the use of so fine a material, and lack of business prevented any expenditures at the time. However, the success of the investigation, the potential saving involved, and the size of the market make this an active project.

Use of fly ash instead of Portland cement as a surface filler for newly laid pavement is entirely successful, but because of the small quantity used is unimportant unless the ash is used as a filler in the mixture as well.

Fertilizer. Use of fly ash as a substitute for sand in agricultural fertilizers appears attractive because of the quantity involved and the stability of the market. Local conditions prevent its use (*a*) because foundry sand can be obtained for the cartage, and (*b*) because fertilizer is made in a food-processing plant where the dust nuisance from the dry ash cannot be tolerated.

Rubber. Fly ash as a filler in rubber, replacing fuller's earth at \$8 to \$12 per ton would involve considerable saving. Preliminary tests which were made in manufacturers' plants, however, showed that it was too coarse as well as too gritty for the purpose.

Primer Paint and Putty. Fly ash instead of calcium carbonate was used in making primer paint and putty. Although good results were obtained, the color of the ash was objectionable for certain paint applications. The small local market made this project unattractive.

Roofing Material. The satisfactory use of ash in paving material suggested its use in asphalt roofing materials. No tests have been made because of the absence of a local market, but shipments have been made to manufacturers of roofing products who reported satisfactory results. It is believed that this project would develop into a successful outlet in localities where these products are made.

Common Brick. Tests were made using 4 per cent fly ash in the mix for making 2000 common brick. Results were very poor. Many of the brick cracked before and during kiln-drying, they were weak and brittle, and the project was pronounced a failure.

Cinder Block. Fly ash has been used to form a dense waterproof outside face on cinder block, thus removing one of the objections to the use of that type of block. This project is not

TABLE 3 DATA ON MIXTURES OF FLY ASH AND AEROCRETE

Cylinder number	Weights of aggregates per mix: Sand, lb	Ash, lb	Cement, lb	Lime, lb	Height poured in cylinder, in.	Height in cylinder after expansion, in.	Increase in height, per cent	Unit weight, lb per cu ft	Unit breaking load, lb per sq in.	Age when broken, days
A7	30.7	None	8.9	0.5	7	$9^7/_8$	41	80	215	40
A8	30.7	None	8.9	0.5	8	$11^1/_8$	39	80	210	40
B7	30.7	None	8.9	None	7	$9^{11}/_{16}$	38	83	165	40
B8	30.7	None	8.9	None	8	$10^3/_4$	35	85	170	40
C7	None	15.0	8.9	0.5	7	$9^7/_8$	41	56	255	40
D7	None	15.0	8.9	None	7	$9^1/_2$	36	61	265	40
D8	None	15.0	8.9	None	8	$10^7/_8$	36	58	270	40
E5[a]	None	15.0	8.9	1.0	5	$8^3/_8$	68	50	190	40
E6[a]	None	15.0	8.9	1.0	6	10	67	50	200	40
F5	30.7	None	8.9	0.5	5	$7^5/_{16}$	46	80	320	40
F7	30.7	None	8.9	0.5	7	10	43	81	325	40

[a] All mixes except E5 and E6 contained 1 oz of the Aerocrete powder and 4 oz of the Aerocrete liquid; the exceptions contained double these amounts.

TABLE 4 TESTS OF LIGHTWEIGHT CONCRETE TILE

Number of specimens	Proportions by volume: Cement	Ash	Sand	First crack: Gross, lb per sq in.	Net, lb per sq in.	Break: Gross, lb per sq in.	Net, lb per sq in.	Weight of tile, lb	Broken in transit, no.
18	1	4	2	53.5	162.5	131.2	400.0	31.2	5
14	1	1.5	1.5	83.3	253.8	179.7	548.0	33.0	6
17	1	2.5	2.5	95.5	291.2	228.3	696.0	34.5	3
6	1	4	4	55.5	169.2	141.3	431.0	34.3	14
3	1	5	5	55.1	168.0	130.4	397.4	35.0	17
3	1	0	4	114.6	349.2	192.3	586.2	34.3	1
3	1	0	7	70.6	215.3	152.5	465.1	37.5	1
4	1	3	2[a]	66.5	202.6	196.0	597.5	33.3	0

[a] Limestone used in this case.

Remarks: All first cracks occurred in the horizontal cross web in tension due to the bowing of the tile walls. Subsequent cracks appeared in the top and bottom walls some time before the ultimate break.

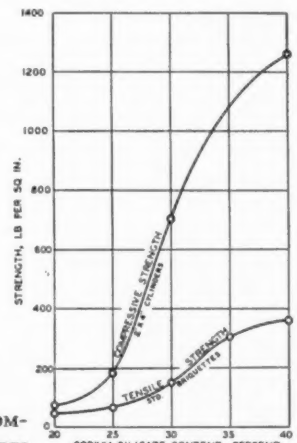

FIG. 3 (RIGHT) TENSILE AND COMPRESSIVE STRENGTH OF MIXTURES OF SODIUM SILICATE AND FLY ASH

now being followed up commercially in the local market, although a market for some ash is anticipated.

FLY ASH AS AN AGGREGATE

Many uses for fly ash have been suggested as an aggregate in various products. Those investigated are sand-lime brick, aerocrete, lightweight concrete tile, acoustic plaster, Haydite concrete, lightweight concrete aggregate, sodium-silicate block, fly-ash-cinder concrete, and Cottrell block.

Sand-Lime Brick. Substitution of fly ash for sand in the standard process of making sand-lime brick was attempted. Tests were made with ash replacing 100 per cent, 50 per cent, and 25 per cent of the sand. The result was a weak structure which cracked and crumbled badly. The strength increased as the proportion of ash was reduced, but most of the brick were unsatisfactory largely because the mixing machinery was not well suited to the use of so fine a material.

Aerocrete. This product is a porous lightweight concrete used to soundproof flooring. A chemical is added to the mix which generates gas and swells the concrete to double its normal volume, thus creating porosity. Fly ash was substituted for sand in the mix. Tests were made and the results are shown in Table 3. The increases in volume fell below that of standard aerocrete, and the project was closed.

Lightweight Concrete Tile. These tile are of thin wall construction similar to hollow clay tile. Because of the known pozzuolanic properties of the ash, it was thought that it might improve the quality of the tile. Table 4 shows results of tests with various mixes. These results are not generally satisfactory; the only one approaching the breaking-strength specification of 700 lb per sq in. required 6 months' aging, which is uneconomical. Furthermore, the machinery for this process is not fully developed for regular commercial uses.

Acoustic Plaster. A preliminary study was made of the use of

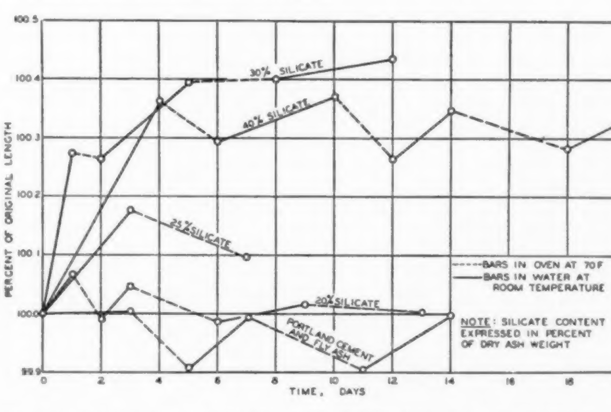

FIG. 4 CHANGE IN LENGTH, DUE TO WETTING AND DRYING, OF BARS MADE FROM SODIUM SILICATE AND FLY ASH

fly ash instead of pumice in acoustic plaster. The color of the ash was a disadvantage and paint applied over it destroyed the sound-deadening effect, which is not so much a function of the material as it is the method of application. Because of the small market involved, this project was closed.

Haydite Concrete. Haydite is an aggregate material made by sintering clay or shale in a rotary kiln and crushing and grading the clinker into standard sizes for use in lightweight concrete.

Standard Haydite concretes are difficult to handle because the light Haydite particles tend to float, while the heavier cement paste settles to the bottom.

The addition of fly ash to the mix stops this tendency to segregate, adds strength to the mix, and reduces the unit weight

of the resulting concrete. Table 5 shows the results of fifty-five 6 × 12-in. specimens tested, comparing the straight Haydite and sand-Haydite concretes with those made with fly ash and Haydite. In spite of the excellent results, the small market and business conditions have prevented its further development.

Aggregate for Lightweight Concrete. It was thought that fly ash might be sintered into a highly vitreous concrete aggregate of light weight. This has been done by The Detroit Edison Company with good results. It was estimated, however, that the cost of the process would render its use in concrete prohibitive. The project was therefore discontinued.

Sodium-Silicate Block. An attempt was made to produce an extruded building block from a mixture of fly ash and sodium silicate. The mixture in economical proportions set too rapidly for extrusion, produced blocks with cracks and checks, gave unsatisfactory compressive strength, and gave indication of spalling badly on outside work. Figs. 3 and 4 show these characteristics. The project was abandoned.

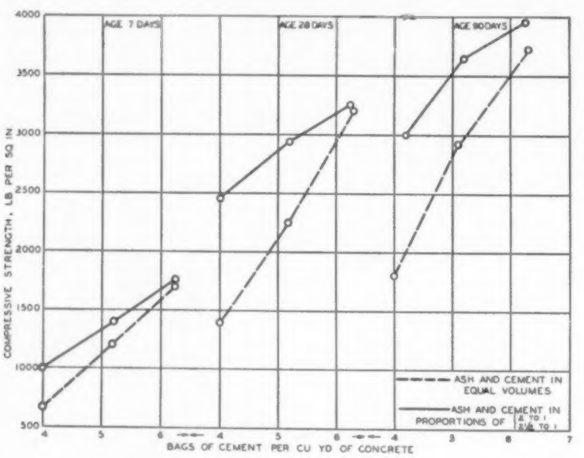

FIG. 5 COMPRESSIVE STRENGTH OF FLY-ASH-CINDER CONCRETE

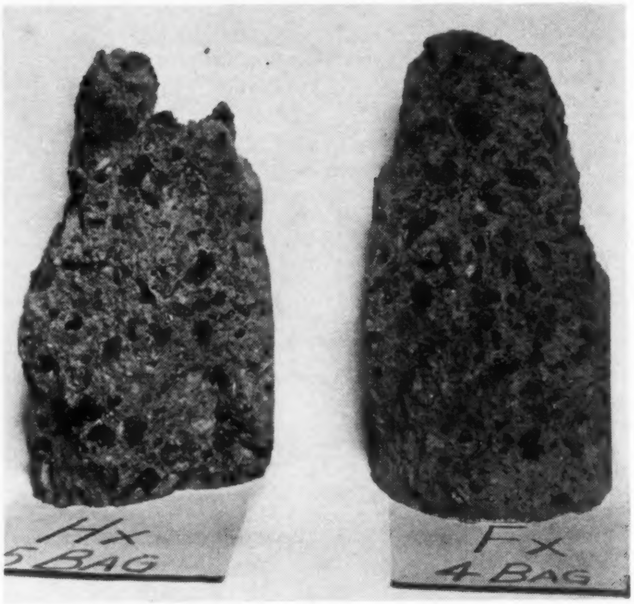

FIG. 6 BROKEN TEST SPECIMENS OF FLY-ASH-CINDER CONCRETE

(Note the density of the lean 4-bag mix.)

Fly-Ash-Cinder Concrete. Considerable work has been done on the use of fly ash as a fine aggregate, with cinders as a coarse aggregate in concrete.

Mixtures of Portland cement, fly ash, and cinders in various proportions have been made and several hundred 6 × 12-in. specimens tested. The addition of fly ash improves the workability of the concrete and increases its density and strength.

Cinder concrete, because of its light weight, is highly desirable for use in steel and concrete buildings, but has been prohibited by building codes because its porosity enables water to attack the steel. The use of fly ash in the mix reduces porosity and removes this objection by building-code authorities.

Fig. 5 shows compressive strengths at different ages for mixes of various cement contents, and Fig. 6 shows the density of the concrete for mixes containing 4 and 5 bags of cement per cu yd.

Cottrell Block. The Detroit Edison Company has been experimenting for several years with the manufacture of Cottrell block made from fly ash, lime, and resin under patents controlled by Rostone, Inc. The process has been described in detail in the literature.[2]

Cottrell block can be made in

TABLE 5 DATA ON MIXTURES OF FLY ASH AND HAYDITE

Type of concrete	Ratio by volume, cement to total mixed aggregate	Mix, parts by volume: Portland cement	Natural sand	Powdered fuel ash	Haydite aggregate, grade	Unit weight of concrete, lb	Compressive strength, average of 5 specimens, lb
Cement and Haydite	...	1	..	..	1½ A 3 C	95.7	1544
Cement and Haydite	...	1	..	..	2 A 3½ C	96.2	1876
Cement, natural sand, and Haydite	...	1	1	..	1½ A 3 C	105.9	2864
Cement, natural sand, and Haydite	...	1	1	..	2 A 3½ C	101.7	1726
Cement, powdered-fuel ash, and Haydite	1–3.8	0.94	..	1	1½ A 2 C	99.4	2700
Cement, powdered-fuel ash, and Haydite	1–5.0	0.71	..	1	1½ A 2 C	98.4	2824
Cement, powdered-fuel ash, and Haydite	1–6.0	0.59	..	1	1½ A 2 C	96.2	2406
Cement, powdered-fuel ash, and Haydite	1–3.8	0.94	..	1	1½ A 1 B 1 C	100.2	3454
Cement, powdered-fuel ash, and Haydite	1–5.0	0.71	..	1	1½ A 1 B 1 C	96.9	3110
Cement, powdered-fuel ash, and Haydite	1–6.0	0.59	..	1	1½ A 1 B 1 C	96.6	2464
Cement, powdered-fuel ash, and Haydite	1–7.0	0.51	..	1	1½ A 1 B 1 C		

[2] See Bibliography (2, 6, 7, 8).

any size required by the building industry. Some of the properties of this material are:

(*a*) Color, slate gray
(*b*) Weight, 100 to 105 lb per cu ft
(*c*) Composition, per cent by weight: fly ash, 90; lime, 10; resin, 0.5
(*d*) Compressive strength, lb per sq in.:
Gross on 8 × 8 × 16-in. hollow block, 1000.
These values exceed A.S.T.M. requirements for brick and hollow block.
(*e*) Thermal conductivity, 3.12 Btu per hr per sq ft per deg F per in.

(*f*) Water absorption:	Range, per cent
After 5 hours' immersion in cold water	5–12
After 5 hours' immersion in boiling water	18–22

These are favorable values for a building material, being low enough to insure a dry wall, yet high enough to assure a good bond with mortar. The absorption varies with the density of the material in accordance with the pressing operation; the amount of resin, an increase of which decreases absorption; and the compacting in mixer or wet pan.

(*g*) Freezing and thawing:
Tests showed the material to be equal to burned clays and other materials in resisting freezing and thawing. A building now more than 6 years old has withstood weathering with complete satisfaction.
(*h*) Thermal expansion:
Up to 1000 F, negligible
At 1800 F, 2.5 per cent shrinkage
Shrinkage begins above 1000 F due to combustion of carbon in the fly ash.
(*i*) Efflorescence:
Efflorescence due to soluble salts was one of the early difficulties with the block. Addition of resin to the mix now converts these salts to insoluble resinates. Subsequent laboratory and field tests have shown complete absence of efflorescence.
(*j*) Friability:
Unfortunately, Cottrell blocks are extremely friable. Extraordinary care must be exercised in handling to avoid broken corners. For particular work, the blocks are packed in corrugated paper cartons to avoid damage.

This block can be used to advantage on many types of construction. Its surface can be plastered, painted, or papered, as desired, and the cells can be filled with loose fly ash to provide thermal insulation. Various buildings have been constructed of this material. Fig. 7 shows the exterior of a house built recently. The walls and partitions are entirely of Cottrell block, waterproofed on the exterior, and painted on the interior. Fig. 8 shows an interior view of the service building of The Detroit Edison Company. The interior partitions are made of Cottrell block 4 in. thick. The wall on the left was painted and that in the center of the photograph was papered to demonstrate the variety of decoration possible.

The Cottrell-block development is one of the most promising of the projects, not only because of the results obtained, but because fly ash constitutes 90 per cent of the mix. Even a partial acceptance of this product by the public might effect the complete disposal of the fly ash from the Trenton Channel plant.

As reported previously, private capital has already shown willingness to assume the manufacture and sale of this product.

FLY ASH AS AN ADMIXTURE

An admixture is a fifth material which is added to a standard concrete mixture of cement, fine aggregate, coarse aggregate, and water. Its purpose is mainly to improve the workability or plasticity of the mix and increase its strength. Powdered-fuel ash is one of the best materials for this purpose.

Tests comprising seventy-eight 6 × 12-in. specimens were made, using two concretes, a lean mix and a rich mix, and various amounts of Trenton Channel fly ash, ranging from 0 to 100 per cent by weight of the cement in the mix. Fig. 9 shows compressive strengths with each point on the curves representing an average of at least four specimens.

It will be noted that the additions of ash improve the strength of the lean concrete in all cases, but show improvement in the rich concrete only for additions up to 20 per cent. In the lean concrete, the workability was greatly improved by ash additions up to 30 per cent, after which the mix became somewhat sticky.

Permeability tests were made on a few specimens which indi-

FIG. 7 RESIDENCE WITH COTTRELL BLOCK WALLS
(Plastic waterproof coating on exterior surface.)

FIG. 8 INTERIOR OF SERVICE BUILDING OF THE DETROIT EDISON COMPANY

(Partitions of Cottrell blocks, one painted, the other papered.)

cated a trend, decrease in permeability with increase of ash added.

From Fig. 9 it is obvious that ash is of more benefit in lean mixes, and suggests the possibility of substituting ash for cement in the richer mixes. Fig. 10 shows the results of tests on sixty-four 6 × 12-in. specimens with ash substitutions for cement up to 21.7 per cent. Such substitutions are possible provided the cement content in the mix used does not drop below, say, 4 bags per cu yd of concrete. It will be noted that the mixtures which include ash show a definite improvement in strength of the concrete with age. For use in concrete, Davis[3] suggests a fly-ash specification of not more than 15 per cent retained on the 325-mesh sieve, and a loss on ignition not to exceed 6 per cent.

FLY ASH AS AN ABRASIVE

Metal Polisher. An experiment was made in the use of fly ash in polishing metal, replacing pumice. Results were poor because the extremely fine material was not sufficiently abrasive for the purpose.

Sandblasting. Use of fly ash for sandblasting has been made by various people. In the plants of The Detroit Edison Company condenser tubes and turbine blades have been cleaned by this method. The results are satisfactory in that a high polish can be obtained with a low loss of metal.

It is understood that fly ash mixed with water has been used at Milwaukee, St. Louis, and possibly in other localities to clean turbine blading, thereby eliminating the dust nuisance. The Detroit Edison Company has had no experience with the wet mixture.

MISCELLANEOUS USES

Portland Cement Manufacture. Use of fly ash as a substitute for a portion of the clay was tried out in one of the local cement plants. Plant tests were made replacing one third of the clay with fly ash. At this rate, this cement plant would consume 150 tons per day of fly ash. Tests on the cement shown in Table 6 give acceptable results. Two local conditions prevent disposal of the ash to this plant: The cost of ash delivered was higher than that of the clay; and in this plant, where the wet process was used, the excessive volume of water required to make a slurry of the fly ash raised the coal consumption for firing the kiln. Where local conditions are favorable, the cement plant may furnish an attractive market for fly-ash disposal.

[3] See Bibliography (9).

Brick-Mold Dusting. Because the brick industry of Detroit consumes about 70 tons of sand per day for dusting brick molds, experiments were made in the use of fly ash for this purpose. Mixtures up to 50 per cent ash were satisfactory, but ash alone caused sticking in the molds. Here again fly ash cannot compete with local prices for sand.

Petroleum Filter. Use of fly ash as a color filter in petroleum refineries was investigated. The refinery, however, reported failure in all attempts to make a suitable filtering material from fly ash.

Foundry Molding Material. An attempt was made to find a use for fly ash in the foundry. No success was obtained in use as parting or molding sand or for cores. As a mold duster it burned in on the heavier castings.

Insulating Material. Tests have been made using fly ash to

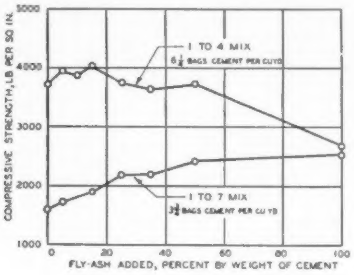

FIG. 9 COMPRESSIVE STRENGTH OF STANDARD CONCRETE WITH ADDITIONS OF FLY ASH

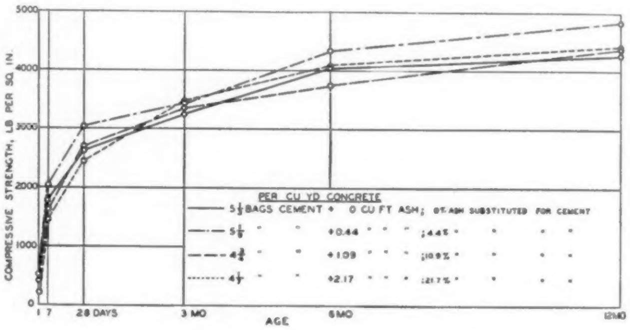

FIG. 10 COMPRESSIVE STRENGTH OF STANDARD CONCRETE WITH FLY ASH SUBSTITUTED FOR CEMENT

TABLE 6 TEST OF PORTLAND CEMENT MADE FROM PULVERIZED-FUEL ASH, CLAY, AND LIMESTONE

	Test No. 1	Test No. 2	Average
Normal consistency, per cent	23.6	23.8	23.7
Initial set, min	150	150	150
Fineness, per cent retained on 200 mesh	10+	11	11
Soundness	O.K.	O.K.	O.K.
Breaking strength of briquet at end of 7 days, lb per sq in	330	325	
	335	310	
	340	315	
	335	285	
Average	335	309	322
Breaking strength of briquet at end of 28 days, lb per sq in	411	386	
	426	409	
	437	465	
	416	403	
Average	422	415	418

fill the cell spaces of Cottrell block for insulating purposes with good results. These have been previously reported.[4]

SUMMARY

The investigation of possible uses for fly ash from a pulverized-coal-fired central station showed that it can be used as a filler in asphalt paving, agricultural fertilizer, and paint and putty; as an aggregate in Haydite concrete, fly-ash-cinder concrete, and Cottrell block; as an admixture in concrete; as an abrasive for sandblasting; as a raw material in the manufacture of Portland cement; and as an insulating material in the cells of hollow masonry walls.

Because of local conditions in the Detroit area, effort has been concentrated toward development of projects using Cottrell block, fly-ash-cinder concrete, concrete admixture, and asphalt paving.

Although The Detroit Edison Company is pinning its hope to these possibilities of solving its fly-ash-disposal problem, all these uses depend on the cyclic activity of the building industry. Another completely independent usage which will absorb the ash not used by the building industry is highly desirable.

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Some Challenging Tax Questions

(*Continued from page 844*)

taxes. By it, many obvious inequalities could be removed—inequalities deriving from the Supreme Court's ruling that the earnings of corporations do not become taxable income of the stockholders until distributed to them as dividends or realized as capital gain by the sale of stock. Social-security taxation is largely omitted from discussion, although it is wisely observed that no reason exists for making social-security rates so heavy that old-age annuity taxes will in effect be covering part of the government's current deficit for general purposes—a condition now prevailing. One other of the conclusions seems worthy of special mention—the need for adoption of such devices and methods as are available for decreasing the duplication and overlapping of the fields of state and federal taxation. Desirable as such a development may be, it must not be accomplished at the price of a dangerous increase in the centralization of power in federal authorities. One method of solving the question would be to clothe the federal government with primary taxing power in all areas and have that agency collect the revenues and redistribute the tax proceeds to the various states as needed. Duplication and overlapping would be checked but state sovereignty would all but disappear. So the problem persists and apparently must continue to do so, as part of the price paid for our justifiable insistence on the security of a decentralized democracy. "Industrial unity will always bring conflicts with political disunity." The most that can be hoped for is a series of compromises, which will remove some of the unfortunate consequences of this fundamental conflict. "Without financial independence, self-government becomes a meaningless label." With financial independence among the several states, local units, and the federal government, difficult areas of conflict cannot be avoided.

Among the concrete recommendations offered, two or three challenge thought. One rather widely held opinion is that the federal income-tax base should be broadened by lowering the exemptions. Arguments to support this recommendation are presented.

Another challenging suggestion is that in place of the undistributed-surplus tax, individuals be required by law to value their shareholdings and enter the plus or minus difference each year in their personal income-tax returns. Net capital losses of any year, as thus reported, would be carried forward into future years until fully absorbed. Obvious administrative difficulties connected with the attempt at annual valuation suggest themselves at once and make the proposal of doubtful wisdom. Supreme Court rulings appear to make the suggestion fanciful, because a law embodying the idea would undoubtedly be held unconstitutional. Only by a constitutional amendment could the idea be realized even if it were administratively feasible. Moreover, tax justice would demand a similar accounting by the owners of all other kinds of property as well as by owners of corporate shares. And so the complexities of the problem would multiply and the administrative difficulties increase. Many will continue in the belief that capital gains and losses would better be eliminated entirely from the area of taxable net income. Finally, and convincingly, the committee recommends that social-security and old-age benefits be placed on a "current cost" basis, after the accumulation of a reasonable reserve for contingencies, and that the pay-roll tax idea be abandoned. Revenues for old-age benefits would be raised by methods of general taxation, together with the contributions of individual employees. Economic and political dangers inherent in an increasingly large old-age reserve fund (which in reality doesn't exist at all except as an accounting item) support the opinion offered. A reserve fund invested in the soundest of securities is indispensable for a private insurance company.

For the government with its taxing power always in reserve, no such need exists. Certain obvious elements of injustice offer arguments to support the abandonment of pay-roll taxes. Prominent among such is the pressure on employers to substitute machines for man power and the practical certainty that in any event the pay-roll tax will be shifted forward in the form of higher prices to consumers.

One outstanding circumstance rises disturbingly in the thought of any person who will consider, even superficially, our national financial situation. Taxes taken increase year by year while the national deficit keeps on growing. Ten years ago something like twelve cents out of each dollar of national income was diverted by taxation into the channels of government spending, including local, state, and federal outlay. Today upward of one fourth of our national income is so taken, yet billions are added annually to our enormous debt. How great indeed is our taxable capacity?

[4] See Bibliography (2)

EXPOSURE TESTS *on* PLYWOOD

Controlled Tests Indicate Durability of Water-Resistant Glue Joints

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PREVIOUS tests have demonstrated that age, in itself, is not a cause of failure in well-made glue joints (1)[1] and that the commonly used woodworking glues are capable of producing joints that are permanently durable so long as the conditions of service do not exceed certain limits. The limits of the service conditions, under which joints made with the more common glues can be expected to remain strong and serviceable, vary with the different adhesives and have been defined by tests previously reported (2). It has been demonstrated further (3) that when a glue joint, originally well-made, fails in service the cause may be chemical hydrolysis of the glue itself, destruction of the glue by microorganisms, or softening and weakening of the glue from absorption of water. These factors are usually combined with and exaggerated by the mechanical stresses developed on the joints as the wood changes dimensions because of changes in moisture content. In joints that are not well-made, the mechanical stresses are sometimes sufficient to cause failure without weakening of the glue material itself. The significance of hydrolysis and its relation to formulation has been developed for casein glues (4) and the general principles are believed to apply to other water-resistant protein glues. It has been shown that adding toxic chemicals to the glue when mixed, or treating the wood with them after gluing, greatly reduces the severity of mold attack (5).

In these previous tests, nothing was found, however, that reduced to a significant degree the failures due to softening and weakening of the glue from absorption of moisture, combined with the mechanical action of the swelling and shrinking stresses in the wood on the glue joint. For highly water-resistant and durable glue joints, a glue must be capable of producing strong joints in the dry condition and be resistant to softening, to hydrolysis, and to mold attack. The common woodworking glues are capable of producing strong joints in the dry condition but soften to a greater or less degree when soaked in water. Some of the more unusual adhesives previously available, such as the cellulose esters, soften very little, if at all, in water but lack the properties necessary to produce strong joints in the dry condition.

The development of the artificial-resin glues provided adhesives capable of producing high dry strengths together with high resistance to softening in water and, consequently, having a high degree of resistance to mechanical stresses. Results of some of the foreign tests (6) as well as early experience at the Forest Products Laboratory with a phenolic resin in alcohol solution (7) were highly promising as far as properties of joints were concerned. When the resin-glue manufacturers had developed their products to a point where they could be offered at a price that the woodworker was willing to pay, the field was opened for a marked advance in the production of glued wood products possessing a high degree of resistance to all forms of exposure involving moisture and a nearer approach to the desired goal of a glue joint capable of withstanding any treatment that the wood itself could withstand.

The evaluation of glued joints requires a long period of exposure to different conditions because methods have not yet been perfected by which ultimate durability can be predicted with certainty from short laboratory tests. Shortly after the synthetic glues were offered on the domestic market, therefore, the Forest Products Laboratory started long-time tests with a view to answering the questions of the actual quality and durability of joints that might be obtained by the use of these newer types of woodworking glues

TEST PROCEDURE

At the time the first of the exposure tests on artificial-resin glues was started by the Laboratory the technic of handling these glues was not widely known and was limited largely to the manufacturers or the individuals who were developing or promoting the respective adhesives. For the purpose of these tests it was decided that the gluing should be done by the manufacturers rather than by the Laboratory. Yellow-birch veneer, $^1/_{16}$ in. thick, selected for smoothness, firmness, straightness of grain, and freedom from defects was sent to the manufacturers with the request that they glue approximately 20 panels, each three-ply, $^1/_{16}$ in. × 12 in. × 12 in., under gluing conditions that they believed most favorable for their particular product. Included in the tests were four artificial resins (P-1, P-2, P-3, and P-4) reported to be of the phenol-aldehyde type and one artificial resin (V-1) reported to be a vinyl ester.

Four types of exposure tests, as described later, were used. The number of specimens glued with resin P-2 was insufficient to provide for all four exposure tests. The specimens available were subjected to soaking-drying exposure because this test is the most important of the four in disclosing the unusual properties of the resin glues. The omission of specimens glued with resin P-2 from three of the four tests necessitates the use of two sets of "control averages" shown in the sixth column of Table 1.

For comparative purposes, twenty similar test panels each were glued at the Forest Products Laboratory with casein and blood-albumin glues.[2] The casein glue was the combination of casein, lime, and sodium silicate described in several publications (8) of the Forest Products Laboratory and the blood-albumin glue, which is also described in Laboratory publications (8), was composed of paraformaldehyde, ammonium hydroxide, and blood albumin.

For the gluing done at the Laboratory, the veneer was con-

[1] Figures in parentheses refer to the Bibliography.

Presented at a meeting of the Wood Industries Division, at High Point, N. C., Sept. 22–23, 1938, of The American Society of Mechanical Engineers.

[2] A straight soybean glue was included in the tests but the results are not reported because the glue was of a type developed for and used extensively on softwoods but not recommended by the manufacturer for use on dense hardwoods. As might be expected, the results on birch were lower than those shown for casein glue and serve mainly to illustrate the fallacy of using on dense hardwoods a glue of insufficient mechanical strength.

TABLE 1 A SUMMARY OF AVERAGE TEST VALUES OBTAINED UPON SUBJECTING SPECIMENS OF BIRCH PLYWOOD TO DIFFERENT CONDITIONS OF EXPOSURE

Time of exposure / Glue	Resin P-1	Resin P-2	Resin P-3	Resin P-4	Average of P-1, 2, 3 and 4	Resin V-1	Blood	Casein
Test Values[1]								
None Dry controls	473-77	435-100	590-74	479-86	(514-79)[2] (494-84)[3]	404-27	447-48	418-5
48 hrs. Wet[4]	460-73	329-92	443-67	375-65	(420-66)[2] (402-74)[3]	275-5	379-51	265-2
Soaked continuously in water								
2-1/2 months	398-90		456-62	350-44	401-65	246-6	368-28	196-0
5 "	421-100		412-74	375-75	402-83	239-8	344-26	151-0
8 "	327-69		387-60	352-14	355-48	214-2	341-31	126-2
12 "	396-73		399-22	301-58	365-51	251-38	305-82	49-0
18 "	399-100		332-90	331-45	354-78	223-52	305-74	8-0
24 "	278-67		284-34	243-46	268-49	183-24	307-66	0-0
30 "	304-72		277-70	278-31	286-58	189-20	238-62	0(25)
36 "	291-100		268-58	242-68	267-75	179-42	232-90	
42 "	233-98		228-100	242-86	234-95	154-64	241-100	
48 "	231-94		229-73	157-48	206-72	117-64	211-93	
Exposed continuously to 97% relative humidity								
2-1/2 months	356-45		414-96	360-05	377-69	277-5	397-90	81-6
5 "	450-98		464-100	354-60	423-86	263-12	340-100	0-0
8 "	328-99		463-100	342-44	378-81	223-0	295-100	0-0
12 "	335-80		477-98	332-63	381-80	301-33[5]	251-100	0(12)
18 "	423-100[5]		446-100[5]	294-62[5]	387-87	262-40	256-100[5]	
24 "	339-73		448-100	290-33	359-69	258-22	215-100	
30 "	319-100		372-82	242-99	311-94	234-2	158-100	
36 "	340-100		434-89	275-100	350-96	245-42[6]	162-100[6]	
42 "	212-100[6]		382-98	194-90[6]	263-96	237-18	131-100	
48 "	353-100		326-100[6]	180-100	286-100	223-37	91-100	
Exposed to a repeating cycle: 2 days soaking followed by 12 days drying in 30% relative humidity								
2-1/2 months	477-97	346-99	448-24	412-100	421-80	211-1	328-20	237-0
5 "	429-74	397-98	487-32	411-46	431-63	90-2	397-0	204-0
8 "	524-89	427-72	512-83	433-32	474-69	130-28	407-29	93-0
12 "	495-60	382-99	483-47	351-61	428-67	58-0	298-0	43-0
18 "	493-76	402-80	427-82	400-46	431-71	28-0	323-40	0-0
24 "	438-92	362-46	446-49	437-78	421-66	0(19)	233-0	42-0
30 "	476-66	394-36	468-54	273-10	403-42		270-0	0(25)
36 "	348-99	279-80	312-68	205-14	286-65		129-0	
42 "	392-46	370-78	490-20	198-3	362-37		135-0	
48 "	345-28	291-65	368-91	187-28	298-53		105-0	
Exposed to a repeating cycle: 2 weeks in 97% relative humidity followed by 2 weeks in 30% relative humidity.								
2-1/2 months	577-77		553-70	395-47	508-65	270-5	383-56	267-2
5 "	497-93		530-86	370-14	466-64	250-4	356-99	251-0
8 "	465-89		451-79	367-8	428-59	204-2	356-98	50-2
12 "	530-92		512-46	408-66	483-68	162-11	332-36	0(12)
18 "	420-94		465-98	372-28	419-73	226-8	359-82	
24 "	401-56		466-71	346-21	404-49	52-0	330-73	
30 "	541-77		489-59	354-22	461-53	64-10	314-30	
36 "	420-88		520-95	306-15	415-66	77-22	279-59	
42 "	537-70		453-41	344-31	445-47	120-8	292-34	
48 "	393-100[5]		489-89[5]	268-0[5]	387-63	92-6	305-57[5]	

[1] First figure in each pair of values is joint strength in pounds per square inch; the second figure is wood failure in percent. Each value is an average of 5 specimens. Figure in parenthesis represents time in months when last specimen failed.

[2] Averages of P-1, 3 and 4

[3] Averages of P-1, 2, 3, and 4.

[4] Tested wet after soaking in water at room temperature for 48 hours.

[5] Slight evidence of wood rot.

[6] Marked evidence of wood rot.

ditioned to approximate equilibrium with 65 per cent relative humidity, giving a moisture content of approximately 12 per cent. The gluing with casein glue was done in the conventional way with conditions adjusted to fall within limits favorable to the production of good joints (8). The panels glued with blood albumin were spread and pressed at room temperatures, allowed to remain under pressure overnight, and then hot-pressed the following morning for 10 min at approximately 260 F under a pressure of 200 lb per sq in.

The procedure after gluing was identical whether the panels were glued at the Laboratory or received from the manufacturers. All panels were conditioned to approximate equilibrium in a room at 65 per cent relative humidity and then cut into standard plywood test specimens (9). Each panel yielded 30 test specimens, giving a total of 600 specimens for each glue.

Five specimens from each panel were tested dry and five were tested wet after soaking for 48 hours in water at room temperatures. If the test values from any panel were low and erratic, that panel was eliminated from further tests. After eliminating defective panels, the dry-test values of the specimens from the remaining panels were averaged for each glue and these averages were used as a basis for comparison throughout the tests. The same procedure was carried out to obtain the wet-test values, although these were not used as a basis for comparison. For each glue, the specimens were then mixed together to insure random sampling and divided into four groups of 75 specimens each, one group for each of the following tests:

1 Soaked continuously in water at room temperatures.

2 Exposed continuously to 97 per cent relative humidity at 80 F.

3 Exposed to a repeating cycle consisting of soaking for 2 days in water at room temperature followed by drying for 12 days in 30 per cent relative humidity at 80 F.

4 Exposed to a repeating cycle consisting of 2 weeks in 97 per cent relative humidity at 80 F followed by 2 weeks in 30 per cent relative humidity at 80 F.

From each group, five specimens were tested at intervals of $2^1/_2$, 5, 8, 12, 18, 24, 30, 36, 42, and 48 months. With the specimens from cyclic exposures Nos. 3 and 4, the testing was done at the end of the "dry half" of the cycle. Specimens from exposure No. 1 were tested wet as soon as possible after removal from soaking and specimens from exposure No. 2 were tested promptly upon removal from 97 per cent relative humidity. The test values for each five specimens were averaged and the averages are shown in Table 1.

The tests are still in progress while this report is being pre-

pared, and sufficient specimens remain to continue the study through the sixtieth month.

In preparing the charts, all successive average values were plotted as percentages of the original average value from the dry tests. This procedure permitted easier comparison of the rates of failure since all lines then start from the same origin of 100. Percentage of wood failure was based on a visual inspection of the broken glue joint and an estimation of how much of the failure occurred in the wood as compared to the failure in the glue line itself. The amount of wood failure was expressed in percentage of the total joint area and in the charts, therefore, the wood failures were plotted as recorded.

In these tests, the specimens were unprotected, the dimensions were small, and the specimens spaced on rods to permit circulation of water or air during the exposure cycles. The wood, therefore, probably attained approximate equilibrium with the exposure conditions at each period of the exposure cycle and the stresses developed on the glue joints approached the maximum that could be expected under the conditions prevailing.

RESULTS

One of the first impressions gained in this study was the importance of the amount of wood failure developed when testing the joints. With the more commonly used woodworking glues the percentage of wood failure was low after any appreciable exposure to moisture. With many of the artificial-resin glues, however, the amount of wood failure developed usually exceeded 50 per cent and often approached 100 per cent. For this reason it seems important to include wood-failure values in tables and charts if an accurate picture of the quality of joint is to be presented. If the percentage of wood failure developed on test approaches 100, obviously the strength of the wood in shear rather than the strength of the bond determines the test value obtained.

Test No. 1. Continuous Soaking in Water. The wet-test values in Table 1 indicate primarily the degree to which the joints are weakened by early softening of the glue, particularly if low strength values are combined with low percentages of wood failures. When long continued, however, soaking in water serves as an approximate measure of the rate or the degree to which the joints weaken by the hydrolysis of the glue itself (3).

Conforming to the results of previous experiments (3), the casein glue hydrolyzed at such a rate that all the joints had failed completely at the end of 25 months and at the end of 18 months the average test value was nearly down to zero. See Table 1 and Fig. 1. This was a casein glue comparatively low in alkalinity. A casein glue high in alkalinity would be expected to hydrolyze more rapidly.

As might be expected from a consideration of their chemical composition, the artificial-resin glues used in these tests did not show a tendency to weaken when soaked continuously in water. If that tendency is present at all, it is masked by the more rapid weakening of the wood itself. When the average figures are plotted, as in Fig. 1, they show a gradual decrease in strength but the average percentage of wood failure at the end of 4 years is some 72 per cent, an amount approximately equal to the average wood failure developed in the original dry tests. The vinyl resin is not included in the averages plotted on the chart but, like the other artificial resins in this respect, it did not appear to weaken any more rapidly than the wood when soaked continuously in water.

The artificial-resin glues, however, are not unique in their ability to resist exposure of this type. The paraformaldehyde blood-albumin glue applied by the hot-pressing method does not hydrolyze at all rapidly. So far as resistance to continuous soaking is concerned, specimens glued with hot-pressed paraformaldehyde blood glue performed as well as the specimens glued with artificial resins.

Test No. 2. Continuous Exposure to 97 Per Cent Relative Humidity. The conditions of this exposure are favorable to the development of fungi. Under these conditions, molds will attack an unprotected protein glue rapidly and wood-destroying fungi will cause rotting in specimens of nondurable and unprotected wood.

The casein glue used contained no chemicals of sufficient toxicity to retard mold growth and the joints made with casein glue failed rapidly, dropping to 19 per cent of their original strength after $2^1/_2$ months (see Fig. 2). After 5 months, the casein joints were so weak that they broke in test before a measurable load could be applied. All specimens glued with casein glue had failed completely by the end of 12 months.

The artificial-resin glues of the phenolic type appear to be resistant to attack by microorganisms. The strength-test values decreased slowly but the percentage of wood failure increased, indicating that the wood was failing more rapidly than the glue and not establishing clearly whether the glue itself had been weakened. At the end of 18 months, visual evidence of rot could be detected in the specimens glued with phenolic resins and after from 36 to 48 months the wood had rotted to a marked degree. Apparently then, the phenolic glues themselves were not attacked by microorganisms but the presence of a phenolic-glue line did not afford protection sufficient to prevent rot in three-ply $^3/_{16}$-in. birch plywood.

The resistance of the vinyl-resin joints was not clearly established by these tests. At the end of 48 months the test values had decreased to some 55 per cent of their original value. The specimens were clearly rotted but the percentage of wood failure did not increase to the extent that might have been expected from the amount of rot present.

Against mold action, the resistance of the hot-pressed paraformaldehyde blood joints appeared to be more than equal to the resistance of yellow birch to wood-destroying fungi. The fact that 100 per cent wood failure was developed in all tests of blood-glue joints in this exposure at the fifth month and thereafter indicated that the decrease in test values was due to a weakening of the wood rather than to failure in the glue itself. The specimens were not examined microscopically for evidence of wood-destroying organisms nor were cultures made but visual evidence of rot could be detected by the eighteenth month and rotting was clearly evident by the end of 3 years. In tests of this type, additional information on the resistance of the glue line itself might have been obtained if tests had also been carried out with a more durable species of wood, such, for example, as the heartwood of southern cypress, redwood, or western red cedar.

Two conclusions from this test should be emphasized:

1 The resistance of the phenolic resins to attack by microorganisms appeared entirely satisfactory but not unique, for hot-pressed blood glues containing paraformaldehyde also proved resistant to this type of exposure.

2 The presence of a glue line resistant to fungi did not prevent rotting of the plywood. The production of plywood resistant to this type of exposure requires a glue resistant to fungi and a species of wood resistant to wood destroyers, or a treatment of the wood with effective preservatives.

Test No. 3. Exposure to a Repeating Cycle That Consisted of Soaking in Water for 2 Days Followed by Drying for 12 Days

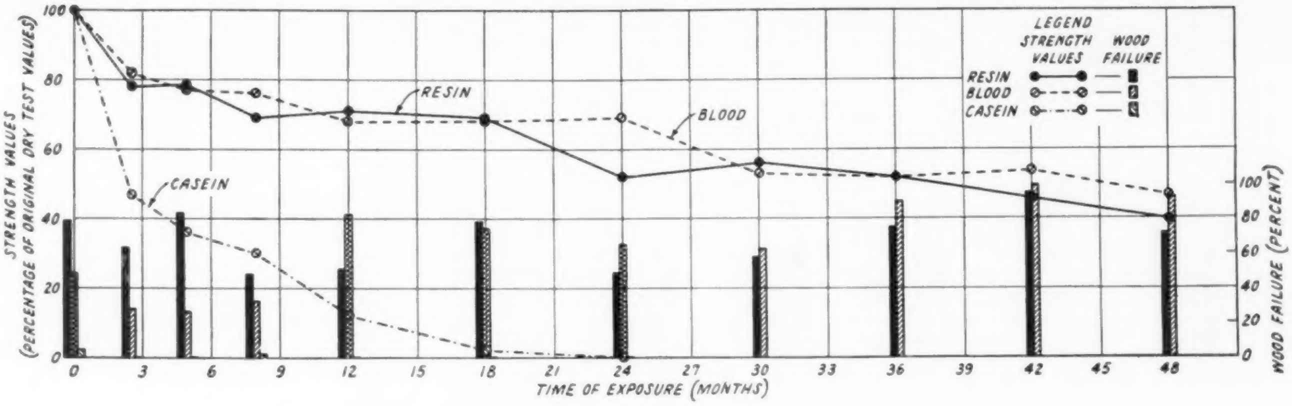

FIG. 1 RATE OF DETERIORATION OF GLUE JOINTS WHEN SOAKED CONTINUOUSLY IN WATER

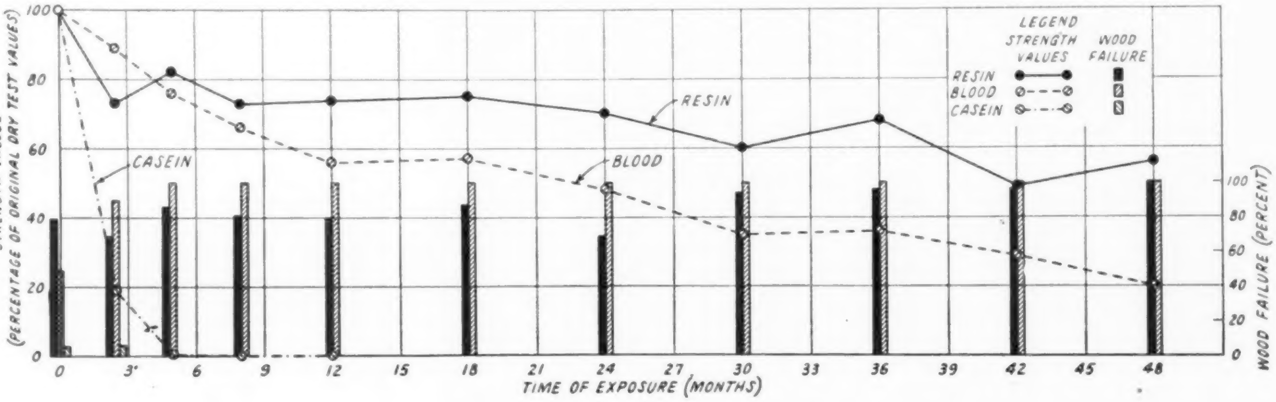

FIG. 2 RATE OF DETERIORATION OF GLUE JOINTS WHEN EXPOSED CONTINUOUSLY TO 97 PER CENT RELATIVE HUMIDITY

in 30 Per Cent Relative Humidity. This exposure, which approached most nearly to exterior exposure conditions, was one that brought out most clearly the superiority of the hot-pressed phenolic-resin glues over the other glues used in these experiments. The casein-glue joints had lost something over 40 per cent of their strength by the first test period of $2^1/_2$ months and had failed almost completely at the end of 18 months, although the last remaining specimens did not fall apart until the thirtieth month (see Fig. 3). Compared with other similar tests on casein glues, these joints were more than usually durable. Similar exposures in other tests have caused casein joints to fail completely within 3 months (2, 3).

At the end of 4 years, joints made with paraformaldehyde-blood glue still retained something over 20 per cent of their original dry strength but the test values showed in general a steady and consistent decrease. The average percentage of wood failure never exceeded 44 per cent and, after eighteen months, no wood failure could be detected by visual inspection of the broken specimens. Decreasing test values and no wood failure indicates a weakening of the glue line. The trend at the forty-eighth month, therefore, indicated that the blood-glue joints were approaching ultimate failure. Similar tests, carried out previously on blood-albumin joints, resulted in total failures at from 25 to 30 months (2, 3).

On the other hand, joints made with phenolic resins have retained an average of 60 per cent of their original dry strength through 4 years of alternate soaking and drying. More important, the average percentage of wood failure in the 4-year specimens was some 53 per cent. The average test values appeared to be decreasing but the fact that a high percentage of wood failure continued to be developed indicated that the severe exposure may have been weakening the wood. At the forty-eighth month there was no indication that the joints would fail more rapidly than the wood itself. These results lend encouragement to the hope that glues may now be available that can withstand exposures as severe as can be resisted by the wood.

In this severe exposure, the vinyl-ester glue line appeared to lack the necessary strength when wet and the joints weakened at a rate which approximated that for casein-glue joints (see Table 1).

Test No. 4. Exposure to a Repeating Cycle of 2 Weeks' Exposure to 97 Per Cent Relative Humidity Followed by 2 Weeks' Exposure to 30 Per Cent Relative Humidity. From the nature and rate of failures it appears that the primary cause of failure in this test cycle was attack by microorganisms. The casein joints failed more rapidly than they did in the soaking-drying test, Table 1, yet it was improbable that the mechanical stresses involved were more severe. The exposure serves to illustrate the probable performance of joints with the different glues exposed in service to dampness and warmth for a period followed by a period of dryness.

As in the tests involving continuous exposure to high humidity, the resistance of paraformaldehyde blood glue was satisfactory. At the end of 4 years the average test value was some 68 per cent of the original dry-test value and the percentage of wood failure was over 50 per cent (see Fig. 4). Slight evidence of wood rot could be detected by visual inspection, indicating that the decrease in test values was due, at least in part, to a loss of mechanical strength of the wood.

As might have been expected from their behavior in other

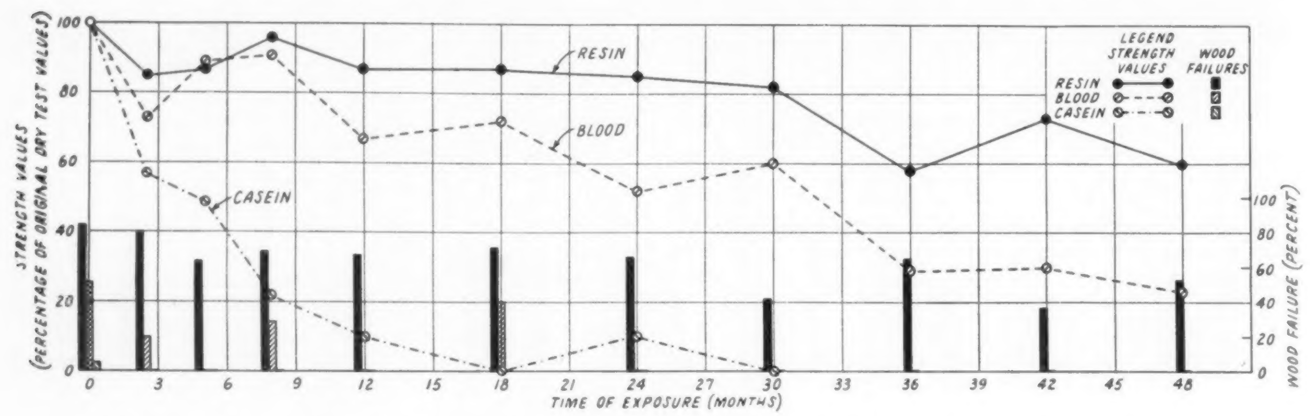

FIG. 3 RATE OF DETERIORATION OF GLUE JOINTS WHEN EXPOSED TO A REPEATING CYCLE OF 2 DAYS' SOAKING FOLLOWED BY 12 DAYS' DRYING

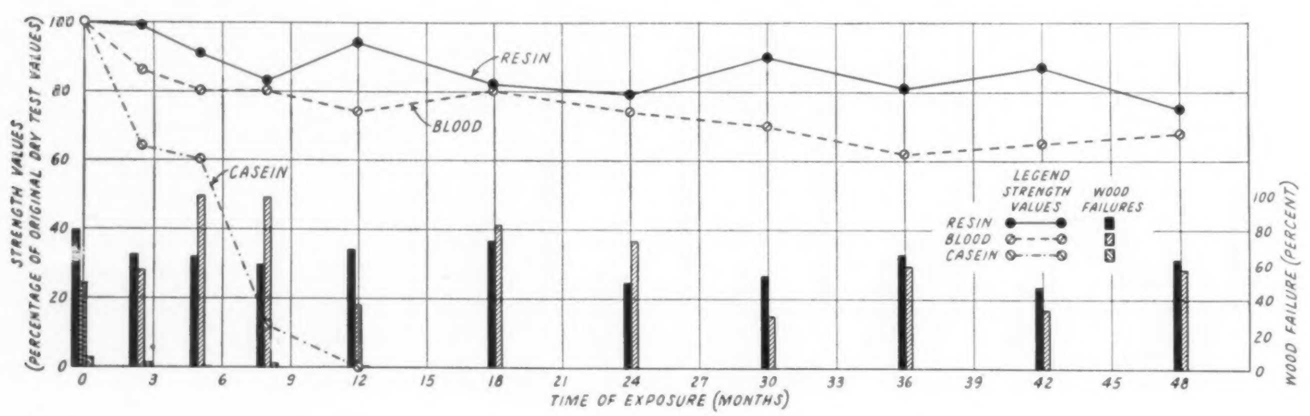

FIG. 4 RATE OF DETERIORATION OF GLUE JOINTS WHEN EXPOSED TO A REPEATING CYCLE OF 2 WEEKS IN 97 PER CENT RELATIVE HUMIDITY FOLLOWED BY 2 WEEKS IN 30 PER CENT RELATIVE HUMIDITY

tests, phenolic-resin joints were not seriously affected by this exposure. A relatively high percentage of wood failure was developed at each test throughout the 4 years. Whatever the decrease in average test values it appeared to be due to a decrease in the strength of the wood rather than failure in the glue. Visible signs of wood rot could be detected in some of the specimens, indicating again that a glue line resistant to fungi does not offer sufficient protection to the wood against fungus attack.

The joints made with the vinyl ester did not appear to be affected by mold and they withstood this exposure much better than they did the soaking-and-drying cycles.

SUMMARY

Joints made with different artificial-resin glues of the phenolic type have satisfactorily withstood 4 years of exposure to extremely severe test conditions. These glues did not appear to soften or hydrolyze on continuous soaking in water and the joints were not affected by molds although the presence of the mold-resistant glue line did not protect the wood itself from the action of wood-destroying fungi. After 4 years of soaking and drying the specimens still developed a high percentage of wood failure in test.

The one vinyl ester included appeared to be sufficiently resistant to hydrolysis and to mold attack but lacked the strength required to withstand stresses caused by repeated wetting and drying.

Previous experiments with the older woodworking glues were confirmed in that: (*a*) The blood glue containing paraformaldehyde was sufficiently resistant to molds and hydrolysis but it lacked the strength to withstand indefinitely the mechanical stresses set up by repeated wetting and drying; (*b*) casein glues were readily subject to failure from hydrolysis, mold action, and mechanical stresses when the glue was softened by absorption of water.

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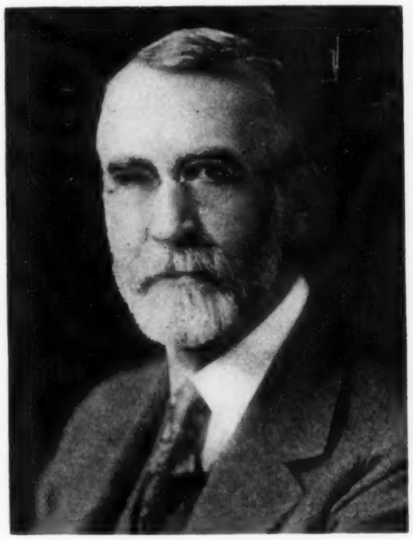
A.S.M.E. HONORS AND AWARDS

II—The Charles T. Main Award

CHARLES T. MAIN, head of a firm of consulting engineers bearing his name engaged in design of textile mills and valuation of mills and water-power companies, member of The American Society of Mechanical Engineers since 1885, and president in 1918, has endeared himself to thousands by his judiciousness, graciousness, and sincerity, especially to students and young engineers because of his great interest in them and their problems. In his presidential address outlining the broader opportunities for the engineer, he pointed out the need of broadening the field of engineering education in order better to prepare the student or graduate engineer for his life's work and place in society. According to him, the training up to 1918 had been "along rather narrow and restricted lines of scientific work, leaving out almost entirely the broader studies of literature, common law, economics, business methods, and the humanities . . . ." "It is essential," he said, "that the engineer should very early in his career acquire some knowledge of business principles and should endeavor to broaden himself so as to be able to fill with fair satisfaction the position that properly belongs to him in his profession and in the world."



CHARLES T. MAIN

Mr. Main also asked that the Society set aside a sum for "prizes and premiums to the younger members for good work." This request was met much sooner than expected when the Council of the Society voted in 1919 "that the sum set aside by Council for the expenses of Charles T. Main, past-president, as delegate of the Society to the Franco-American Congress in Paris (discussion of reconstruction plans for France), and subsequently returned by Mr. Main (who paid the expenses himself), be placed as a special account for establishing an award to be known as the Charles T. Main Award."

As soon as Mr. Main heard about the action of Council, he wrote a letter to Calvin W. Rice, Secretary of the Society, in which he said, "I do not think that the sum is sufficiently large to be of real use for any purpose and, if such a fund is to be established, I would like to contribute more to it." His check for the additional amount was enclosed.

Early in 1920, the Council voted "that the income from the Charles T. Main Fund be used for a cash prize of $150, to be known as the Charles T. Main Award, to be presented in any given year to a student member of the Society for the best paper written within the general subject of the 'Influence of the Profession Upon Public Life.'"

The second of a series of articles, prepared under the direction of the Board of Honors and Awards of The American Society of Mechanical Engineers, better to acquaint the members of the Society concerning the honors and awards which are given in recognition of meritorious achievements of engineers.

The topic for each year's competition together with a suitable bibliography is developed by the Board of Honors and Awards, after consultation with distinguished engineers throughout the country, and assigned, subject to the approval of the Council of the Society. Each paper submitted must not be less than 2000 words in length, and must be the original work of the student member. All manuscripts must be received by June 30 at Society Headquarters in order to be eligible for that year's award.

On or before October 1, all papers submitted are read and the best one is selected, adjudged from the standpoints of applicability (practical or theoretical), value as a contribution to mechanical-engineering literature, completeness, originality of matter, and conciseness. Originally, this work was performed by the Board of Honors and Awards, but in recent years, because of the increasing duties of the Board, it has been done by the Committee on Relations With Colleges. Acting upon the recommendation of the Board, the Council announces the name of the winner during the Annual Meeting in New York and presents him with the cash prize, together with an engraved certificate.

Several schools are accepting Charles T. Main Award papers as graduation theses or for college credit. Papers are also being entered by student members for the cash-prize awards given at the regional student-group meetings and the special student sessions under the sponsorship of local sections of the Society.

RECIPIENTS

The Charles T. Main Award was first given in 1925 and, since then, has been made every year except in those years when papers entered were not up to the very high standards established by the Board of Honors and Awards. That the Board has been successful in its selection, is evidenced best by the subsequent careers of some of the recipients as outlined in what follows from information gathered from various sources.

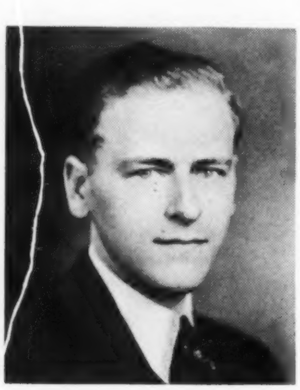
Clement R. Brown, 1925 recipient from Catholic University of America, wrote on "The Influence of the Locomotive on the Unity of the United States." After being graduated from the University of Michigan in 1924, Mr. Brown continued his studies as a graduate student at Catholic University and received his M.E. degree in 1926. He started his engineering career at the National Bureau of Standards as a junior engineer, became an assistant physicist there in 1928, and a fire-resistance engineer in 1936. Meanwhile, he continued his studies at the University, receiving the doctor of science degree in 1934. Dr. Brown has written many papers on the study of fire resistance; his latest on "Fire Tests of Treated and Untreated Wood

MARSHALL ANDERSON

CLEMENT R. BROWN

JULES PODNOSSOFF

ALLAN P. STERN



GEORGE D. WILKINSON, JR.

G. LOWELL WILLIAMS

Partitions," was published in a recent issue of the *Journal of Research*, National Bureau of Standards.

WILLARD C. SAYLOR, 1926 recipient from Johns Hopkins University, discussed the subject of "The Effect of the Cotton Gin Upon the History of the United States During Its First Seventy Years." After being graduated in 1927, he became assistant sales manager with Flynn & Emrich Co. of Baltimore, Md.

ROBERT M. MEYER, 1928 recipient from Newark College of Engineering, had for his subject, "Scientific Management and Its Effect Upon Manufacturing." He was graduated in June, 1928, with the highest academic honors and a degree of B.S. in M.E. Even while he was in school, as part of the system of cooperative industrial education of the Newark College of Engineering, he worked in various manufacturing plants. After graduation, he obtained much industrial-engineering experience with various manufacturing and engineering companies, including the Wright Aeronautical Corp., Armstrong Cork Co., and Hamilton Watch Co. From Nov., 1936, he was a wage-incentive engineer in the plastics division of E. I. du Pont de Nemours & Co. at Arlington, N. J. During his brief career, Mr. Meyer suffered two long spells of illness; the aftereffects eventually resulted in his death on May 6, 1938.

JULES PODNOSSOFF, 1930 recipient from the Polytechnic Institute of Brooklyn, described "The Value of the Safety Movement in the Industries." Prior to his graduation in 1931 with the degree of M.E., *cum laude*, Mr. Podnossoff was elected honor student of his class and also received the Institute's Alfred Raymond Award for the best thesis submitted that year. In 1931, he received a second award from the A.S.M.E. when his paper on "Pressure and Energy Distribution in Multi-Stage Steam Turbines Operating Under Varying Conditions" won for him the Society's Student Award. Following his graduation, he was awarded a fellowship at his alma mater in the mechanical-engineering department. He completed his graduate work and received the master of mechanical engineering degree in 1933. The following three years, Mr. Podnossoff was affiliated with General Electric Appliances, S. A., in Argentina, where he was in charge of engineering in the refrigeration department, in which capacity part of his duties included cooperation with public-utility companies in the organization of service shops throughout the country. Since 1936, he has been employed by the General Electric Co. of South America at its Buenos Aires office as sales and application engineer in the air-conditioning department.

ROBERT E. KLISE, 1931 recipient from the University of Michigan, wrote on "Interchangeability—Its Development and Significance in Industry." Starting at the age of twelve and continuing up to a few years ago, Mr. Klise worked after school and during vacations for the Blackmer Rotary Pump Company in various capacities. In 1933, he received a B.S. in M.E. degree from the University of Michigan. While working for the Blackmer company, he designed and developed a new type of pump. At the present time, he is engaged in business for himself as a development and design engineer. Since becoming a junior member of the A.S.M.E. in 1933, Mr. Klise has been active in Society affairs, serving as secretary-treasurer of the Peninsula Section since 1935.

MARSHALL ANDERSON, 1932 recipient from the University of Michigan, had for his subject, "Apprenticeship and Vocational Training." After being graduated in 1932, he continued his studies at the University under a Tau Beta Pi fellowship and received his master of science degree in 1933. After working for the Consumers' Power Company, he entered the test department of the General Electric Company in Schenectady. Since March, 1936, Mr. Anderson has been in the induction-motor engineering department where he works on electrical and mechanical problems encountered in the operation of induction motors under actual service conditions.

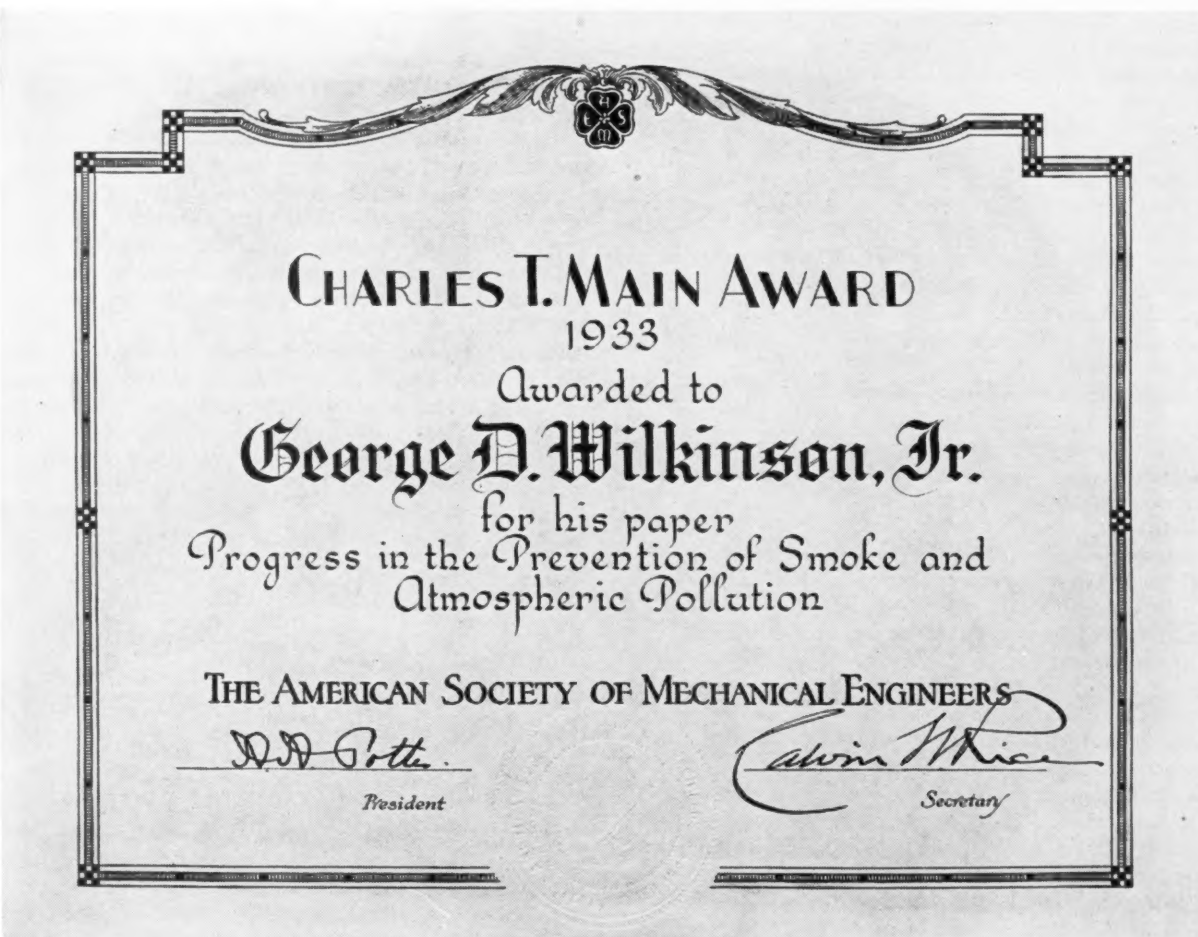
GEORGE D. WILKINSON, JR., 1933 recipient from Newark College of Engineering, had for his subject, "Progress in the Prevention of Smoke and Atmospheric Pollution." After graduation, he became an assistant at the College. In 1934, Mr. Wilkinson worked as an industrial engineer with United Parcel Service in New York, making time studies and setting rates for the sorting and delivery of packages. He went back to his alma mater in September, 1935, as an instructor in industrial management, economics, accounting, and staff control, and became an assistant professor in 1938. Columbia University gave him a degree of M.S. in industrial engineering in June, 1937, after he had completed the necessary studies in his spare time.

PHILIP P. SELF, 1934 recipient from Colorado State College, submitted a paper on "Air Conditioning—Its Practicability and Relation to Public Welfare." After graduation, he taught for a while in the Denver public schools. His subsequent whereabouts are unknown.

G. LOWELL WILLIAMS, 1935 recipient from Lafayette College, wrote on "Coordinated Transportation—An Economic Comparison of Railroad, Bus, Truck, Water, and Air Transportation for Long and Short Haul." After his graduation in 1935, Mr. Williams was employed by the General Electric Company under its business-training course plan in several sections of the accounting department. Having finished his training course, he entered the department of business and engineering administration of the Massachusetts Institute of Technology in September, 1938, to complete his study for a master's degree.

ALLAN P. STERN, 1937 recipient from the Case School of Applied Science, had for his topic, "The Influence of the Introduction of Labor-Saving Machinery Upon Employment in the United States." Upon graduation in 1937, Mr. Stern was employed by The Colonial Iron Works Company of Cleveland as an engineer, specializing in design and layout of conveyer systems and of labor-saving equipment.

EDWARD M. CONNOLLY, 1938 recipient from the University of Detroit, described "Economic Limitations in Engineering Design—With Concrete Examples." He was graduated in June, 1938, with the degree of B.S. in M.E.



THE CERTIFICATE WHICH ACCOMPANIES THE MAIN AWARD
(Reproduced through the courtesy of Professor Wilkinson, 1933 recipient of the Charles T. Main Award.)

BRIEFING THE RECORD

Abstracts and Comments Based on Current Periodicals and Events

MATERIAL for these pages is assembled from numerous sources and aims to cover a broad range of subject matter. While few quotation marks are used, passages that are directly quoted are obvious from the context and credit to original sources is given.

Day by Day

SEPTEMBER brought abundant demonstration of the grim and confusing impact of science on society, so frequently mentioned in these pages, in the narrowly averted war in Europe. What science and engineering have done to enlarge the theater of armed conflict the world was learned in China, in Ethiopia, and in Spain. That incidents of the wholesale slaughter of innocents, destruction of property far from the actual lines of conflict, and interruption of essential services without which modern cities fail to function might be repeated in the British Isles, no one doubted. Modern means of communication leave no one ignorant of what these horrors are, and hence aided powerfully in stimulating the great urge for peaceful settlement that was so convincingly demonstrated in the manner in which the heads of four governments were greeted, encouraged, and applauded in their efforts to avoid war. The airplane and the telephone quickly brought together the few men in whose power the decision for peace or war was held. The radio kept the world informed, aroused its passions and its fears, but provided also a means by which public opinion was quick to form in a manner that leaders assessed and interpreted. Science stood on both sides, as ready to intensify the horror of war as it was to facilitate the maintenance of peace.

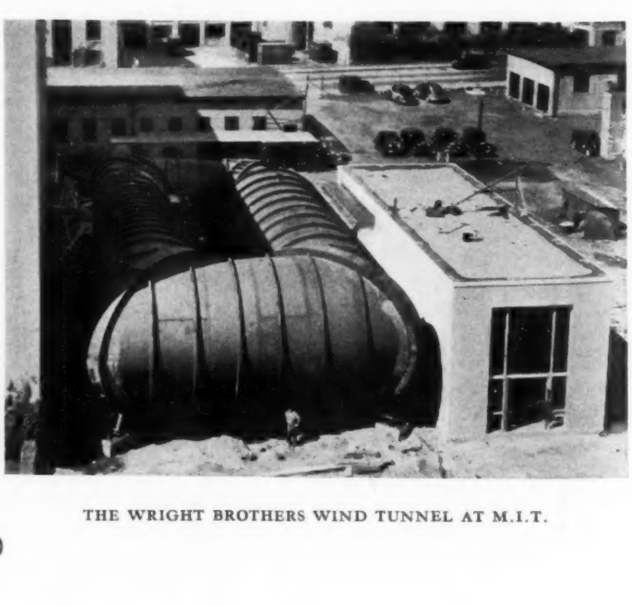
Although the day-by-day uncertainties of the European situation were reflected in fluctuating prices of securities and commodities, economic recovery in the United States, which became evident in the late spring, continued to go forward and to encourage the hope that better times lie ahead. Figures of the National Industrial Conference Board showed a steady rise in employment to a total of 43,453,000 in August. About 369,000 fewer persons were reported unemployed in August than in July. The total unemployment figure of 10,590,000 included 3,475,000 workers in the government emergency labor force, as represented by the WPA, the CCC, and the Federal Projects Works Program. Steel production rate of 47.9 per cent on October 4, is expected to increase as the automobile building program of the fall gets into its stride; and the aggregate net profits of the automobile industry for the last quarter of 1938, it is predicted, will exceed the entire return during the first nine months. Building contracts in August reached the highest level since July, 1937, and corporate flotations rose to the largest total since June, 1937.

On the darker side must be reckoned the fact that much of the work of the world is still being expended in armament programs, and no such supreme faith in "peace in our time" seems to exist as will cause nations to abandon their expensive preparations for an armed peace at best. The problems of agricultural prices and crop control still beset this country. The railroads have added to their troubles the controversy over a reduction in wages, now being studied by an able fact-finding board comprising Judge Walter P. Stacey, of the North Carolina Supreme Court; James M. Landis, dean of the Harvard Law School; and Prof. Harry E. Millis, of the University of Chicago. Nor must it be forgotten that the government is spending billions of dollars in an effort to stimulate business, and that politicians are finding believers in slogans that promise "thirty dollars every Thursday." Labor is still divided against itself. Day by day it is being convincingly demonstrated that in matters of national and economic well-being, the engineer is becoming more importantly involved than ever before.

Wind Tunnel

On September 12 the Wright Brothers Wind Tunnel was dedicated at the Massachusetts Institute of Technology "as a memorial to the methods of controlled experiment consistently applied by the Wright Brothers in their historic conquest of the air." Speakers at the dedication included Dr. Godfrey L. Cabot, of the Corporation of the Massachusetts Institute of Technology; Griffith Brewer, of the Royal Aeronautical Society of Great Britain, whose subject was "The Contributions of the Wright Brothers;" Dr. George W. Lewis, of the National Advisory Committee for Aeronautics, who spoke on the value of the wind tunnel in aeronautical research and design; and Karl T. Compton, president, M.I.T., and member, A.S.M.E.

The new tunnel, which is the seventh built at the Institute since 1913, was made possible by funds voted by the corporation and the gift of a substantially equal amount by a number of donors. For the accompanying photograph of the exterior of the tunnel we are indebted to the builders, the Pittsburgh-



THE WRIGHT BROTHERS WIND TUNNEL AT M.I.T.

Des Moines Steel Co. The tunnel is described in the dedication program as follows:

The wind tunnel is essentially a closed, welded, cylindrical, steel circuit in which a 2000-hp electric motor with variable-pitch propeller moves the air at high speed. The general form is similar to that first developed by Prof. L. Prandtl. Compressing the air in the tunnel to four atmospheres simulates conditions of full-scale flight, and exhausting to one-quarter atmosphere represents density conditions at high altitude, and gives higher speed for the power available.

The experimental section where models are exposed to the air stream is an ellipse 10 $\times$ $7^1/_2$ ft. It is expected that a maximum velocity of 400 mph will be available for one-quarter atmosphere pressure, and for four atmospheres, a Reynolds number of 6,500,000.

Speed control is accomplished by means of pole changing, combined with variation of the pitch of the propeller. Aerodynamic forces and moments on a model airplane are to be measured against the forces required to maintain the equilibrium of a supporting balance having six degrees of freedom. Force indications are transmitted electrically to dials in the control room where they can be recorded.

Batt

Engineers who picked up *Forbes* magazine for September 15 were pleased to see W. L. Batt looking up at them from his desk, for his photograph was prominently displayed on the cover, and to read, inside, the pen picture by Morgan Farrell of the president of the SKF Industries and past-president of The American Society of Mechanical Engineers.

Mr. Batt's most important recent contribution to public service was as chairman of the Coordinating Committee of the Seventh International Management Congress, which met in Washington, September 19 to 24, and which recognized Mr. Batt's qualities as a management leader by electing him president of the International Committee on Scientific Management.

Mr. Batt is known to hold positive, constructive, and progressive opinions on subjects relating to industry, management, and labor relations. A recent expression of his views on "Management's New Responsibilities" created favorable comment when it appeared in *Dun's Review* for August, 1938. The following excerpt from this article provides an excellent example of Mr. Batt's thinking:

"People must live, and they should have a reasonable certainty that so long as they do and are willing to work, they can have at least the necessities of life. We already have a small measure of unemployment relief and old-age benefits. If industry itself cannot give income the year around and security after a man's working days are over, popular opinion is likely to force the Government to enlarge this program.

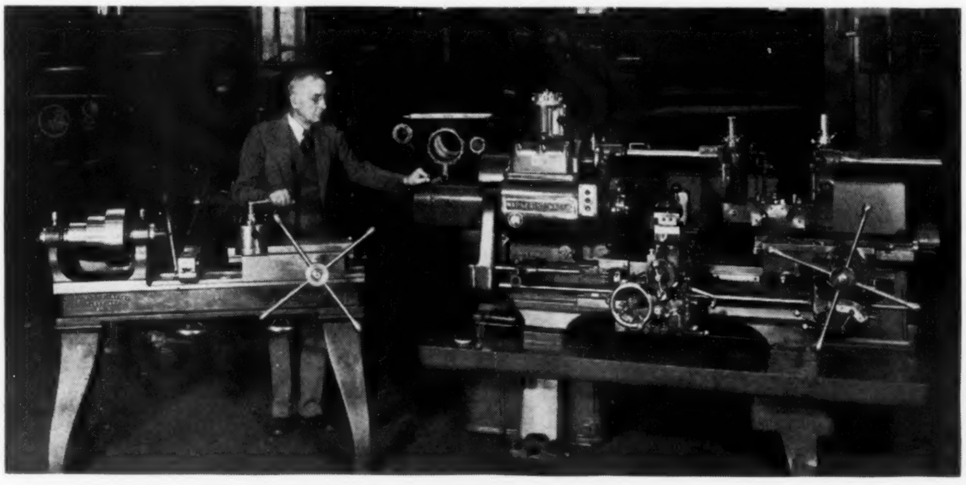
"In short, if business does not succeed in finding the means to give job security it will have to pay the bill indirectly through taxes. And that will always be the most expensive way.

"I do not know specifically how these things should be worked out, but I know it is high time we do some straight thinking, with the probable result that we shall have to change many of our traditional ideas.

"For example, even though all employees and many employers maintain that a workman is not a machine, most employees would be physically better off if they were treated like machines. This could be amplified in many ways and at great length. I want to make just one point. We buy our machines outright, except in a very few cases where they are leased, and after we have acquired them we must keep them, in good times and bad. No machine manufacturer would consider renting out a vaulable machine on the basis that rent was to be paid for it only when it was in use, and that it need not be taken care of when a plant shutdown made it idle. Yet that is the way the custom of years has arranged things with our factory employees."

Barclay

News has been received of the death on Sept. 16, 1938, of William R. Barclay, 1938 Rice Memorial Lecturer of The American Society of Mechanical Engineers, whose lecture, "Contributions of Metallurgy to Engineering Progress" was published in the August and September issues of MECHANICAL ENGINEERING. Mr. Barclay, who was prevented by illness from undertaking the trip to the United States in the spring of 1938 to deliver the lecture, was consulting metallurgist of the Mond Nickel Company, Ltd., of London, England, and served for two years, 1936 and 1937, as president of the Institute of Metals.



EVOLUTION IN TURRET LATHES

(George A. Decker, Warner & Swasey Company works engineer and oldest employee, comparing a machine built when he joined the firm fifty years ago with the fifty thousandth turret lathe completed by the company during the week of October 3. The old machine is going to Henry Ford's museum in Dearborn, Mich., the new one to the Pratt & Whitney Aircraft Company in East Hartford, Conn.

Control of Small-Plant Purchases

A.S.M.E. FALL MEETING, PROVIDENCE, R. I.

PROCUREMENT of materials, supplies, machines, tools, and services for a business is the primary function of its purchasing department. But, according to W. C. Zinck, member, A.S.M.E., and purchasing manager, North and Judd Mfg. Co., New Britain, Conn., in a paper presented at the Fall Meeting of The American Society of Mechanical Engineers, Providence, R. I., Oct. 5–7, 1938, this is not all which has to be considered. An abridgment of the paper follows:

Purchases must be made at a cost consistent with economic conditions surrounding the material purchased and safeguarding the standard of quality and continuity of service. Furthermore, purchases must be controlled because sales at a profit in a competitive field cannot be made unless materials being used in manufacture are bought at a cost as low as that enjoyed by competitors and because investment in inventory must be kept at a minimum in these times.

This control of purchases in a small plant, says Mr. Zinck, may be secured by making an analysis by weeks and months of the procurement and disbursement averages for the last three years. Based on these figures, the purchasing manager asks three or more suppliers to submit bids for all the materials to be supplied as needed. It is felt that the penalty exacted for buying in small quantities is negligible in a small plant. If possible, a supplier should be small because his relations with the small plant are more flexible and the quantity of business more desirable than would be the case with a large supplier. Close cooperation between supplier and purchasing department will permit the mutual development of a satisfactory schedule of supply. The only objection to this plan is that some suppliers will balk at supplying free warehouse service for the small plant, but this matter is conveniently forgotten when and if the supplier obtains the order.

All companies, big and small, should have a budget in order to control expenses. With a purchase budget, records must be set up so that the inventories of the different classes of materials can be controlled. The basis of this record is the financial principle that no invoice shall be passed for payment unless checked as to whether the material specified has been actually received. Consequently, as complete a stock record can be kept as the value of the item warrants—from a complete perpetual inventory to a mere entry of receipt.

But purchase records alone do not provide budgetary control. It is also necessary to compare the amount spent against the figure set up in the budget and to compare the quantity bought with the amount used in operations. This is particularly true in a plant manufacturing a multitude of items of various sizes, shapes, and styles from many kinds of materials, depending on the purchaser's specifications. However, an examination of previous years' figures will show that the law of averages holds true and that the proportion of total purchases to the total sales does not vary to any great extent. Consequently, all the purchasing agent has to do is to keep the expenditures for purchases within an established percentage of the sales.

Based on experience, economy is obtained by having the purchasing department exercise control over the raw materials and supplies through stock-room records which are under its supervision. But, since the different items making up the total sales will vary in style, size, and material from season to season, even though sales figures remain the same, the purchasing agent will need more than his stock-room records to guide him in his purchases in order to keep within the budgetary allowances and to have the necessary materials on hand when required.

This control may be obtained through an "Analysis of Purchases" (parts of the form shown in Fig. 1) which is figured weekly. The basic principle behind this method is to set up side by side the two checks on purchasing, i.e., "placements vs. budget" and "placements vs. disbursements," the cumulative differences between the two items of each check serving as the keys to control.

On the analysis sheet, total purchases are divided into major

Quarter Totals															
MATERIAL															
	TOTAL 20							PIG-IRON 21							
	$ Budget %	Placements $	Placements % Ord.	Disbursm'ts $	Disbursm'ts % PPP	Accum. Diff. Budget vs. Plcmts.	Accum. Diff. Plcmts. vs. Disbrts.	$ Budget %	Placements $	Placements % Ord.	Disbursm'ts $	Disbursm'ts % I.F.P.P.	Accum. Diff. Budget vs. Plcmts.	Accum. Diff. Plcmts. vs. Disbrts.	$ Bud
1															
2															
3															
4															
10															
11															
12															
13															

CONDENSED ANALYSIS										
	Week Ending	Orders	Plant Productive Payroll	Budget %	Placements $	Placements % Orders	Disbursements $	Disbursements % P.P.P.	Accum Diff. Budget vs. Plcmts	Accum Diff. Plcmts. vs. Disbts
1										
2										
3										
10										
11										
12										
13										

FIG. 1 PARTS OF THE FORM—ANALYSIS OF PURCHASES

(Showing (top) an example of the detailed weekly analysis made for each purchased item and (bottom) a condensed analysis of all purchases and disbursements for the week.)

divisions, such as materials, supplies, and fuel, with enough subdivisions (e.g., pig iron, brass sheet, plating) under each heading to give an adequate picture of the week-by-week fluctuations. The budgetary percentages allowed for each division and subdivision are adjusted annually. Sales are calculated from incoming orders, placements are based on purchase orders issued, disbursements to the various departments are obtained from the stock record cards and reports from producing units in the plant, e.g., foundry metals and fuels, are taken from the daily cupola- and furnace-charging schedules. For those items of materials and supplies bought from time to time as needed and sent directly to the departments which ordered them, it is assumed that the value of placements is the value of the disbursements.

It has been found by analysis that some items can be expressed approximately as a percentage of the plant production pay roll (P.P.P.) or a department production pay roll, such as iron foundry (I.F.P.P.). This is based on the assumption that for every dollar spent for productive labor, quantities of material and supplies of a definite value have been used.

Cumulative differences between placements and budget, and placements and disbursements are figured after the budgetary, placement, and disbursement items have been deter-

mined. If placements exceed budgets or disbursements exceed placements, the entries are posted in red.

Use of the analysis, which does not require the collection of additional data, makes it possible to determine whether the purchasing agent is buying too much and increasing inventories or whether he has permitted the quantity of raw materials and supplies to decrease to the danger point. If placements are ahead of the budget for a group in which disbursements are in excess of placements, it shows that the budgetary amount is not sufficient, and a thorough investigation should be made of the reasons for the variation from the long-time average. With the use of the analysis, financial and production phases of purchasing are kept in balance, inventories are not increased without just cause, and waste through substitution is not possible.

With the aid of the aforementioned records and analysis sheet, the purchasing agent is in a position to justify decreases and increases of expenses for raw materials and supplies as brought out in the plant's profit-and-loss statement. By co-operation with the accounting department, the purchasing department can supply valuable cost data to the general manager for guidance in operating the plant efficiently and economically.

Labor in Akron and Great Britain

FACTORY

DURING the summer, *Factory* made two significant contributions to a better understanding of one of the most vexatious questions of our times—labor relations. In the July issue of this magazine, a factual study looks into the heart of the "Labor Boomerang in Akron." In the August issue, a keen observer of industrial conditions who has visited the principal industrial countries of the world writes on "Britain's Way With Labor." Thus from both sides of the Atlantic—in one case dealing with a specific industrial center and in the other with the labor policy of an entire country—facts and figures are unearthed that provide excellent grounds for the forming of opinion.

In his case history of labor strife and decentralization in Akron, Mr. Coates presents a discouraging picture that supports his contention that "everybody loses in a labor war." Contrasted with this dark picture is the hope held out by Edward J. Mehren that when we in this country shall have passed through the period of industrial turmoil that grips us today we may emerge, as he seems to have found that Great Britain has done, into a saner atmosphere of mutual cooperation between management and employee, between associations of manufacturers and labor unions.

The lessons that Mr. Coates summarizes from Akron's bitter experience are well-stated in his own words: For industry there is a warning against putting all your production eggs in one basket, or in one city. For labor there is a warning that you are killing the goose that laid the golden egg when you enforce high wage differentials to the detriment of the city that suffers from them. For other communities there is a warning that constructive efforts to save an overcentralized city cannot be begun too soon.

The lesson for America that Mr. Mehren announces at the beginning of his "report" is that we may profit from Great Britain's experience. "America," he says, "must soon choose between voluntary and compulsory systems of labor negotiation and adjustment. Already we are set in the compulsory direction—in the Wagner Act and in our railway conciliation—with turmoil and much employer unhappiness in one and packed results in the other. Do we want an extension of these methods or are we quickly to change our front and welcome and encourage a voluntary system? In making our momentous decision the experience of Great Britain should be helpful. They have voluntary agreements. How do they work? What do employers and unions say about them? The answer is unanimous: Both agree fully that voluntary agreements do work. Both vigorously oppose compulsory labor agreements and government intervention."

Readers who have not seen the two articles referred to will do well to read both of them at one sitting, for the lessons each has to offer are strengthened by the contrasting conditions that are reported.

Color in Industry

STEEL

INDUSTRY is finding that color is an important factor for better, faster, and more efficient work in the manufacturing plant, according to an article appearing in the Aug. 15, 1938, issue of *Steel*.

When a shoe manufacturer changed the color of his machines from black to orange, the contrast between machines and product made seeing easier and a better quality of workmanship was apparent at once. Fatigue and nervous tension were reduced, accidents lessened, and an interdepartmental rivalry for greater cleanliness developed. Most important was the sharp rise in speed-of-production curves.

For a "cool" atmosphere, green has been found to be the ideal color. Blues, also, are suitable except for the darker shades. A white ceiling, medium shade of pea green for upper walls and large vertical areas, and gray-green for dado, columns, and machinery, have been found effective in eliminating complaints of excessive warmth. For a "warm" atmosphere, yellows, orange, and buffs are suitable. They are excellent for rooms with lower-than-normal temperatures.

To reduce eye strain, paints with high light reflectivity are used for large expanses in the room so that a minimum of light is lost. To relieve nervous tension, green is valuable because of its "friendly" appearance. Softer shades of yellow also create amiability. Gray should be avoided because it depresses.

To stimulate physical energy, red and reddish orange are best. To command attention and for danger areas, red appears the ideal color because of its sharp, contrasting nature and psychological association with blood.

One Type of Industrial Training

1938 ANNUAL MEETING, THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

MANY MEN in industry are furthering their technical training at home by study through correspondence-school courses. Some institutions, including the Refrigeration and Air-Conditioning Institute of Chicago, are supplementing this education by mail with practical training in a shop or laboratory, according to a paper by Ray D. Smith, president of the Institute, that is to be presented at the 1938 Annual Meeting of The American Society of Mechanical Engineers under the auspices of the Society's Committee on Education and Training for the Industries.

Organized in 1934, the Institute of which Mr. Smith is president is managed by a board of governors, consisting of representatives of air-conditioning and refrigeration equipment manufacturers. Meeting every other month, the board discusses and directs the school's activities, including advertising,

preparation of descriptive pamphlets, home-study courses, and laboratory training. This control by industry is exercised without its having a dollar invested in the Institute and without its assuming any financial obligation.

The complete course, consisting of about a year and a half of home study and four weeks of intensive practical training in the school's laboratory, costs each student slightly more than $200. Even though the Institute is operated on a profit-making basis, Mr. Smith asserts that every dollar of profit has been put back into the school, since its inception, in order to broaden the scope and efficiency of the training.

It is interesting to note that the Institute maintains a psychological research department which, among other things, makes studies as to the most effective method of presenting a certain subject, including the utilization of a vocabulary, developed at Columbia University, that is adaptable to the normal educational level of the men who are enrolled. The department has also developed tests for educational proficiency and mechanical aptitude which are used as a basis for the acceptance and rejection of student applications.

However, even with this care in selection, only about one student in every five is able to complete the home-study course and come to the laboratory for his practical training. The student who graduates possesses the necessary knowledge and skill to do practically any kind of a service or installation job. Nevertheless, Mr. Smith is frank in saying that the men who graduate must get one or two years' experience in the field before they can hope to obtain the full benefits of the training given by the Institute.

Positive-Displacement Pump

MECHANICAL WORLD

DESCRIPTION of a type of pump in which the pumping action is obtained by the interaction of two sets of rollers, is contained in *Mechanical World* for Sept. 2, 1938.

The two sets of rollers are shown in Fig. 2; one set being con-

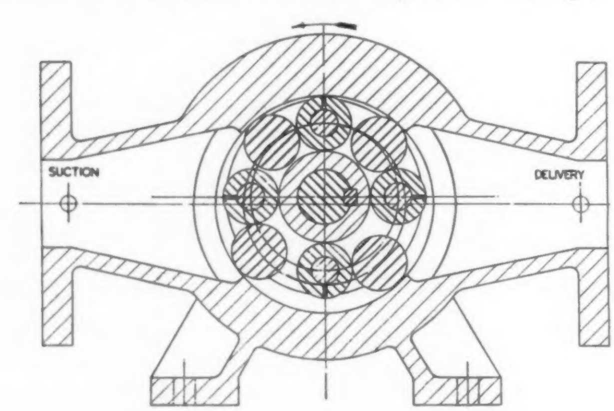


FIG. 2 DIAGRAM OF POSITIVE-DISPLACEMENT ROLLER PUMP

strained by the way the rollers are mounted on pins to travel in a circular path concentric with the axis of the pump shaft, while the other set are free rollers which travel in another circular path of larger diameter than, and eccentric to, that of the first set of rollers.

The combined effect of the eccentricity and difference in diameter is a cyclical variation in the volumes of the series of cells bounded by the rollers, which in conjunction with suitable suction and delivery ports, produces the pumping action. In view of the fact that the only parts of the pump in contact are rolling, it is possible to run the pumps at high speeds; generally it is possible to connect direct to a prime mover or electric motor, without any intermediate reduction gear. The pump gives a steady flow and pressure and, owing to its design, can be made to have any number of sets of rollers or cycles of operation per revolution.

Steam-Generating Turbomotor

THE ENGINEER

A SELF-CONTAINED steam generator and turbine, designed for vehicular transport, is described in *The Engineer* of June 10, 1938. It is said to be the invention of a French engineer, who has built and tested a 35-hp experimental unit which produced 50 bhp when operating at a speed of 1800 rpm and a steam pressure of 425 psi. The apparatus is shown diagrammatically in Fig. 3.

The motor consists of a series of hollow disks mounted on a shaft; the interior of each disk being divided into two parts by

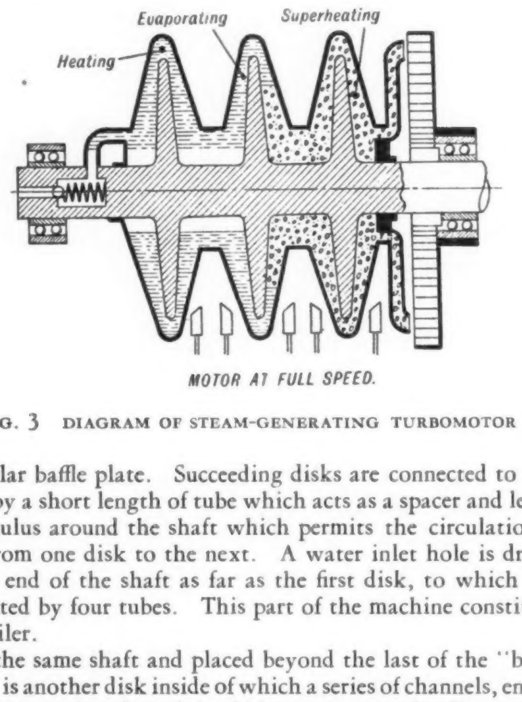


FIG. 3 DIAGRAM OF STEAM-GENERATING TURBOMOTOR

a circular baffle plate. Succeeding disks are connected to each other by a short length of tube which acts as a spacer and leaves an annulus around the shaft which permits the circulation of fluid from one disk to the next. A water inlet hole is drilled in one end of the shaft as far as the first disk, to which it is connected by four tubes. This part of the machine constitutes the boiler.

On the same shaft and placed beyond the last of the "boiler disks" is another disk inside of which a series of channels, ending in nozzles at the edge of the disk, are machined. These channels connect with the hollow of the last boiler disk, thus permitting the steam in the boiler to escape by the nozzles. A ring consisting of a series of fixed turbine blades held between two plates fixed to the frame of the motor is arranged round the outside of the nozzle disk. When the steam escaping from the nozzles strikes the blades, the reaction causes the shaft carrying the boiler disks and nozzles to revolve.

Under the boiler disks, a gas or fuel-oiler burner is used as the source of heat. The entire motor is enclosed in a heat-insulated casing, at each end of which is a bearing in which the shaft of the motor rests. Water is fed to the boiler by gravity and suction. Because of the position of the nozzles at the end of the motor it is not possible for the boiler disks to fill completely with water, for when the water reaches the outlet of the last disk it runs out by the nozzles. The quantity of water in the boiler is, therefore, very small, being only about 5

quarts in the motor now completed. The burner under the boiler is arranged so that the flame heats the last of the boiler disks first and then passes around inside the casing and around the motor in a spiral; the exhaust gases leave by a flue at the front of the first boiler disk.

The nozzles are controlled by a valve which permits the steam in the boiler disks to be turned on when a sufficient quantity has been produced to start the motor. The centrifugal force causes the water at first to spread in a ring around the periphery of the disks, leaving the center of the disks free for the collection of steam. As steam forms in the last boiler disk, it forces the water in that disk back, causing it to flow into the preceding disks so that the boiler disks at the outlet end tend to become filled with steam only. When the motor reaches full operating speed the steam pressure will have acted to fill the first disks with water, and the last disks with steam. The boiler is thus divided into three zones, the first serving for heating the water, the second for its evaporation into steam, and the last for superheating the steam which then escapes by the nozzles.

The escape of the steam causes a natural flow of the fluid toward the nozzles, aided by centrifugal force in the revolving boiler. When the motor is running at full speed, it actually sets up a suction which draws water from a reservoir, which is so placed that when the motor is at rest, the level of the water in the boiler is the same as that in the reservoir.

The exhaust steam is led to an air-cooled condenser, similar in construction to an ordinary automobile radiator. This condenser is designed so that the cooling of the steam will be only sufficient to condense it, the water leaving at a temperature close to the boiling point to go to the reservoir from which it is drawn by the suction of the motor as it is needed. The air, after passing over the condenser, is used as secondary air for the burner, which is placed under the revolving boiler.

Brazing Copper Boiler-Tube Ends

A.S.M.E. SUBCOMMITTEE ON WELDING

SINCE copper tubes, mechanically fastened into the steel heads of 225-psi vertical fire-tube boilers used on electric locomotives, tend to work loose because of repeated heating and cooling and the vibration of the locomotive, a new method had to be found for bonding the tubes to the heads. After experimenting with various methods, one was developed in which the copper tubes are brazed to the steel heads with a silver alloy, according to a paper presented by A. M. Weir and H. M. Webber, at Detroit, Mich., Oct. 18, at a joint session of the A.S.M.E. Subcommittee on Welding, and the American Welding Society. The complete paper was published in the October issue of *The Welding Journal*. Consequently, only a brief description of the new process will be given in the abstract of the paper which follows.

After constructing several small sample units, a full-size unit was designed and built. It consisted of 1237 phosphorous deoxidized copper tubes $35^3/_4$-in. long, fitted into two steel heads 48 in. in diameter and $^3/_4$ in. in thickness. But the tubes instead of being expanded and ferruled as was done previously (see Fig. 4), were fitted into the heads for brazing as shown in Fig. 5. Prior to assembly, the two steel heads were fastened together and the necessary number of holes bored in both at the same time. Then each head was counterbored to provide a recess in each hole for a band of silver brazing alloy, 0.050 in. thick by 0.25 in. wide, the inside top diameter being about 0.003 in. larger than the outside diameter of the tube which provides for easy assembling. The alloy was composed of 50 per cent silver, 15.5 per cent copper, 16.5 per cent zinc, and 18 per cent cadmium.

Following this, the bored openings were cleaned to remove all dirt, oil, scale, and oxides. The copper tubes were thoroughly cleaned by bright-dipping in a chemical-solution bath. The tube ends and the bored holes were then coated with a thick solution of flux and water, and the silver-alloy rings placed in the counterbored recesses in the heads and also coated with flux. The tubes were then inserted. A steel screen was fastened at the bottom of the assembly to hold the tubes in place, and supports welded to the heads held up the top-tube-sheet head. These supports were designed so that the upper tube sheet could be lifted from them by the expansion of the copper tubes during heating.

Then the assembly had placed over it a nonoxidizing bell-

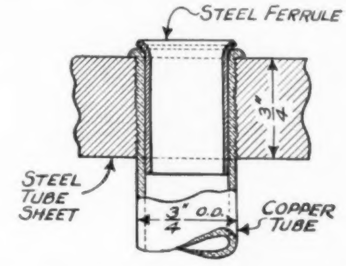


FIG. 4 CROSS SECTION SHOWING OLD METHOD OF BOILER CONSTRUCTION IN WHICH COPPER TUBES ARE EXPANDED, BEADED, AND FERRULED IN STEEL HEADS

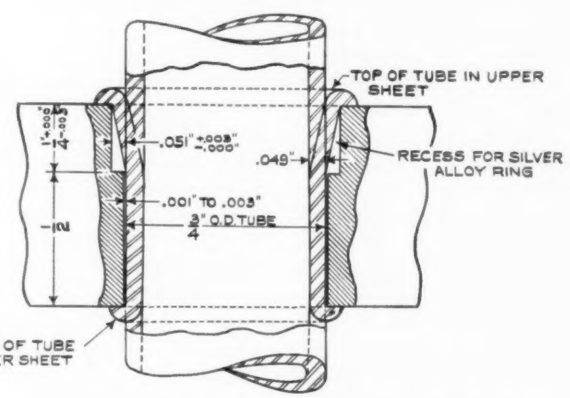


FIG. 5 COMPOSITE CROSS SECTION SHOWING NEW METHOD OF BRAZING AND BEADING OF COPPER TUBES IN STEEL HEADS

type electric furnace, consisting of two parts, an inner retort and the outer heating unit. Temperature readings were made with the aid of thermocouples placed in various locations in the assembly. When the temperature reached 1160 F, which is just beneath the melting point of the silver brazing-alloy rings, the power was turned off for 15 min to allow the cool portions to reach the temperature of the hot portions. When a temperature of 1238 F was reached, the power was turned off and the furnace heating unit removed. The inner retort was then sprayed with water to accelerate the cooling.

The tube assembly was then subjected to a series of rigid tests to determine the tightness and strength of the brazed joints prior to the beading of the tube ends as shown in Fig. 5. Consequently, the strength of the tested joints was solely that imparted to them by the silver brazing alloy. When the unit was tested hydrostatically at 330 psi, no leaks were apparent under this pressure. The next test was a series of 45 steaming cycles in the boiler, each cycle consisting of raising the pressure from

zero to 225 psi and then shutting off the burner and bringing the boiler down to zero pressure. Each cycle was accomplished as quickly as possible in order to develop maximum strains in the assembly. After the twenty-fifth cycle, the severity of the test was materially increased by emptying the boiler of all water and steam at the end of the cycle and then pumping cold feedwater into the dry, hot boiler. Despite all these tests, which greatly exceeded conditions found in actual practice, the brazed joints remained leakproof.

Following these tests in the shop, the completed boiler was put in actual service by installation in an electric locomotive used for hauling passenger trains. On Sept. 1, 1938, the fire-tube boiler had been in service about three months, still in the same conditions as when first installed.

The higher cost of the brazed-tube assembly is expected to justify itself by a reduction in maintenance costs. It is also hoped that this construction will eliminate the retubing of the boiler every four years as is usual now, thus making possible a further saving of approximately $500.

Physics and the Future

SCIENCE

IN AN address entitled "Physics and the Future," delivered at Ottawa, June 29, 1938, before the American Association for the Advancement of Science, reported in *Science* for August 5, 1938, Arthur Compton, Nobel prize winner in physics, of the University of Chicago, directed a portion of his remarks to the subject of power. He said:

Perhaps the most significant mechanical advance of the last century, however, was the development of sources of power, steam and gas engines, and water turbines. The efficiency of conversion of potential and chemical energy into useful work by these engines has increased from an original few per cent to a value so high that though further advances are possible they cannot greatly alter the power situation. We are favored for the time being with plentiful supplies of fuel in coal and oil. Within a century petroleum will have to be extensively supplemented by artificial liquid fuel, a procedure already followed in Europe. Within a thousand years the more readily available coal will be approaching exhaustion. New sources of power will thus gradually become of importance. Sources now available include agricultural products, such as wood and alcohol, water power, wind power, and direct solar heat. Of these, perhaps that of agricultural products has the greatest promise of becoming a major power source. It is apparent, however, that unless fundamentally new developments occur, future generations will not be as favored as we are with regard to available power.

One of the major problems of the physics of the future is thus to investigate all sources of energy which show promise of being important. A hopeful lead is the inexhaustible flow of energy from the sun and stars in the form of radiant heat. Geological records indicate that for a billion years the sun has poured heat upon the earth at about the same rate as it now comes to us. Chemical energy, such as coal burning in oxygen, could not supply this power for more than a thousand years before the sun would cool. Within the last twenty years several theories of stellar heat have been put forward, the most promising of them based upon atomic nuclear reactions similar to radioactivity. In the laboratory, it has been found that such nuclear reactions can be produced and are capable of supplying heat in the necessary amounts. We do not yet know, however, how these nuclear reactions are made to occur efficiently on the sun, nor have we any assurance that they can be brought about on earth in such a way as to act as a source of energy.

There is thus no reason to be pessimistic with regard to power supply. It may require a decade, a century, or a thousand years, but there appears no reason to fear man's inability to find an adequate new supply before the failure of power sources now developed limits the advance of society.

It is evident that we have only begun to appreciate the many uses of power. Heat, artificial light, and running water have become almost universal in this country. Refrigeration, including air conditioning, is rapidly expanding its usefulness. Electric power and heat in the home, power for transportation and for industry—here is a trend that is upward, with no limit now in sight. The trend in the electrical distribution of power seems to be toward placing power plants near sources of fuel or water power, and transmitting the energy by high tension. Here physical problems of electrical insulation and electrical resonance are involved. Great improvements in high-voltage insulation and very possibly use of direct current will make possible much farther transmission at much higher voltages.

The efficiency of electrical motors, generators, transformers, and heaters is already so nearly perfect that further improvements in this direction are unimportant. There is considerable room, however, for improvement in the efficiency of electric lighting. Though notable advances have been made within the last generation, it remains theoretically possible to produce more than ten times as much white light for a given expenditure of power than is now given in ordinary house lighting. The fluorescent lighting now being introduced marks another important step toward high-efficiency lighting; but more remains to be accomplished.

Special mention should be made of the physicist's studies of low temperatures, using liquid helium at fractions of a degree above absolute zero. Here the ordinary physical properties of elasticity, heat capacity, and electrical conductivity are greatly altered. Recent developments have made this extreme cold accessible without great difficulty. We have not yet found important industrial uses for such low temperatures, but there is good reason to anticipate significant scientific advances from studies in this field.

Mechanical Cotton Pickers

AGRICULTURAL ENGINEERING

MUCH PUBLICITY has been given recently to the invention of a mechanical cotton picker. Some persons have seen in the cotton picker a mechanical device which is certain to create a major economic and social disturbance in the cotton-producing areas. However, despite this pessimistic prediction, the development of the Rust and other mechanical cotton pickers has not yet reached the point where the machines are commercially available for general use, according to an editorial and five articles appearing in the September, 1938, issue of *Agricultural Engineering*. The following summary, prepared from these articles, outlines the problems and mechanical difficulties which are besetting the designers and inventors of cotton harvesters.

Cotton picking involves the selection and separation of mature bolls with a minimum of injury to the living plant and immature bolls. It requires a selectivity based on color or texture. It necessitates movement of the picking agency to the material, and either considerable dexterity of individual movement or a complicated uniform movement of the picking mechanism in the plant space to gather high, low, inside, and outside

bolls of low individual unit value. To meet all of these and numerous other mechanical, biological, economic, and human problems with one machine is difficult, as evidenced by the rate of progress to date.

As nearly as can be determined by information obtained from the U. S. Patent Office, it appears that approximately 850 patents have been granted on cotton-harvesting devices since 1850. In numerous cases several patents have been granted on various features of the same machine. The field of promising cotton-harvesting machines is now confined mostly to a relatively few companies: The International Harvester Company, the Rust Brothers, Wind-Roll Cotton Picker Co., the Texas Agricultural Experiment Station, and George R. Meyercord and Associates.

Hundreds of early attempts failed because they did not satisfy the basic requisites for cotton picking which are: The harvesting of a high percentage of the mature cotton without seriously damaging the picked cotton, the plants, or the immature cotton bolls; sufficient capacity to make the operation profitable; the gathering of cotton free of leaves, stems, hulls, and weeds mixed with the lint; mechanically dependable and easily serviceable units; and units which may be attached to a farm tractor rather than a more expensive self-propelled outfit. Claw-fingered gloves proved a handicap rather than an aid to the hand picker. Manually operated devices of all kinds, intended to make hand picking easier and faster, actually did the opposite.

Early machines with either vertical or horizontal spiked drums or disks not only injured the plants by the raking action of such mechanisms, but gathered little of the cotton, and dropped on the ground most of that which was thus clawed out of the bolls. Machines having rotary brushes likewise were failures, as were machines which dragged chains bearing hooks through the plants. Pneumatic pickers of either the pressure or suction type have failed because of the excessive power required for their operation; and the great amount of dirt, leaves, and trash sucked in with the cotton by vacuum-type machines, have made them unsatisfactory.

The main types of mechanical cotton harvesters developed in recent years are of the stripper and the picker types. The stripper device is designed in such a way that the burrs and much foliage are incidentally removed along with the cotton by stripping the plants between stationary slots or revolving rolls. The picker-type machine is designed to pick the open cotton from the bolls by means of spindles or fingers. These harvesters often leave an appreciable amount of cotton on the ground, and some cotton on the stalks.

Mechanical harvesters, such as strippers and spindle pickers, have thus far produced seed cottons in which leaf and other particles of foreign matter have become entangled in such a manner as to be difficult of removal by cleaning equipment in the gins. The large leaf particles are too large to be screened out and excessive handling through cleaning and drying equipment may shatter them with attendant lowering of grade.

The Bureau of Agricultural Economics, U. S. Department of Agriculture, reported last year that spinning tests of cotton harvested with a mechanical cotton picker which was extensively publicized have revealed that even with the use of full batteries of gin cleaners and extractors, the machine-picked cotton was of appreciably lower grade and yielded much more manufacturing waste than hand-picked cotton from the same field and similarly treated. Cotton harvested early in the season by machine was more wasty, because of the green leaf picked with it, than cotton gathered later when the leaves had dried.

The latest International Harvester cotton picker, which has received little publicity in the daily press, is a single-row type provided with two vertical and parallel revolving cylinders between which the cotton plants pass as the machine moves forward along the rows. From each cylinder protrude 154 spindles, or 308 of them in all for the single-row machine. Each of these spindles has numerous tiny needles or barbs which catch the lint. The rotative speed of the picker drums is synchronized with the traveling speed of the tractor so that the rotating projecting picker spindles enter and withdraw from the plants without any raking action. As the rotating spindles penetrate the plants and touch the lint of the open bolls, the barbs catch the cotton and extract it, and as the drums carry these cotton-laden spindles around, the cotton is removed by doffers which rotate in close proximity to the spindles at a higher rotary peripheral speed than the spindles, and thus remove the cotton. The cotton then falls on a conveyer belt which carries it to a suitable receptacle.

Similar in operation is the "Gyracotn" cotton picker developed by George R. Meyercord and associates. Instead of being a unit attached to a tractor, such as the International Harvester machine, the Gyracotn's construction embodies an engine to drive it through the fields and to operate its various parts. Small picker points driven entirely by friction, are attached to the two rolls between which the cotton plants pass. These points are small rugged hooks rapidly rotating as they come in contact with the cotton. The nature of the cotton is so different from other parts of the plant that the blunt hooks engage it with great ease but take up nothing else. They engage the cotton by a twisting action; separate it from the plant by twisting and pulling; carry it into the machine, and then throw it off by a reversal of the twisting action. The hooks are then treated with a polishing brush and go out to repeat the process. Meanwhile, the cotton which has been thrown off by the hooks is delivered to a large collection box by the air conveyer, which blows it against a grill, thus deflecting the loose cotton downward into the collection box and allowing dirt and other foreign particles to escape into the air.

In 1930, a tractor-mounted roll-type stripper was developed and tested on several varieties of cotton by the Texas Agricultural Experiment Station. With this model 88.6 per cent of the cotton on the plant at harvest was harvested. But this percentage was too low. To improve this machine studies were made to determine the effect of size of stripping rolls, the angle of the rolls to the ground, the best material and type of surface for high efficiency, the rate of tractor travel, and the relation of peripheral travel of the rolls to tractor travel. By means of such studies, the redesigned cotton stripper in last year's tests harvested an average of 97 per cent of the cotton at College Station and 98.8 per cent at Lubbock. After cleaning, the cotton was rated only one grade below cotton picked from the same field by hand.

According to the authors of the various papers, the cotton pickers developed today have been fairly successful, considering variations in types of cotton plants, and also variations in habits of growth of the same type of plant from season to season in different kinds of soil. The heights of the plants and their spread of branches varies so greatly that it offers quite a handicap. The ginning industry has yet to find a satisfactory means for overcoming the difficulties presented in the ginning of mechanically picked cottons of existing characteristics.

Based on the results obtained with various kinds of mechanical cotton pickers, there is being developed today at the Texas Agricultural Experiment Station a cotton plant especially suitable for mechanical picking or stripping. This plant will have a restrictive vegetative growth, a determinate fruiting habit, relatively large storm-proof bolls borne in semiclusters but singly on long thin peduncles, and a small leaf.

Other factors which hinder the use of a mechanical cotton

picker are topography of the field, including percentage of the slope, straightness of the rows, and the number of terraces; size of farm (50 per cent of farms in 12 cotton states are under 100 acres in size); acres of cotton grown; average yield; the low price of cotton; and availability of labor at harvest. Also, a man owning a farm of 100 acres or less could hardly afford to pay $1500 to $2000 for a mechanical cotton picker.

Synthetic-Silk Fiber

U. S. PATENT OFFICE

CHALLENGING the ingenuity of mechanical engineers will be the design and development of suitable machinery for the mass production of a synthetic-silk fiber discovered by Dr. Wallace Hume Carothers, brilliant du Pont chemist, who helped to develop Neoprene, a rubber-like product, in 1931. Patent No. 2,130,948 for the new fiber was issued posthumously to Dr. Carothers on Sept. 20, 1938, according to a brief announcement in the *Official Gazette* of the U. S. Patent Office.

In the new patent, fiber experts believe that they have at last discovered the long-awaited substitute for natural silk. Containing 56 broad and basic claims, the patent describes the production of synthetic fibers from polyamides derived from diamines and dibasic carboxylic acids, obtained not from the cellulose of growing plants as rayon is from cotton or wood, but from coal and its highly important coal-tar derivatives. Eight specific ways of creating the new fiber are described.

The new fiber, says the patent, is an outstanding contribution because it is made entirely by synthetic means and has the unusual property of being very strong, flexible, elastic, and insensitive to moisture to a high degree. The excellent recovery of the fabric, after stretching up to 700 per cent, makes it "especially useful in the preparation of knitted wear, such as stockings, gloves, sweaters, underwear suits, etc." While fibers can be easily drawn to a size equal to the diameter of a natural silk filament, or in some cases to only one seventh the diameter, it is also possible to produce much larger filaments which are useful as bristles, artificial straw, fishline leaders, musical-instrument strings, dental floss, horsehair and mohair substitutes, and the like. These bristle filaments are said to have "good snap, toughness, and resistance to water."

The fibers even have a luster like silk, but it is easily possible to treat them and reduce or destroy this luster, says the patent. Two of the delusterants which may be used are zinc oxide and carbon black.

Based on newspaper reports, it is believed that the cost of materials used in the fiber's preparation will make it more costly than rayon. Whether it can compete with silk in cost, depends on the machinery and production plans developed by engineers, especially mechanical engineers.

Single-Sleeve-Valve Engines

S.A.E. JOURNAL

THERE is no reason, A. H. R. Fedden, president of the Royal Aeronautical Society of England, predicts in his paper appearing in the September, 1938, issue of the *S.A.E. Journal*, why the single-sleeve-valve aviation engines should not eventually supplant completely existing poppet-valve engines with their fundamental major mechanical problems. The paper starts by giving a historical background of the sleeve-valve internal-combustion engine from 1905, when Charles Y. Knight first began the work on his subsequently famous engine, through 1909, when Peter Burt, a Scotch engineer, and James McCollum, a Canadian engineer, simultaneously invented the single-sleeve-valve engine. The paper then continues with a description of the development by different groups until The Bristol Aeroplane Co., Ltd., of England, entered the field. There then follows a résumé of Bristol single-cylinder research, and subsequent complete engine development giving particulars of type tests, together with flight testing of the Bristol sleeve-valve engines. Altogether more than 10,000 hr of main-engine running and flying have been attained on the Bristol sleeve-valve type of engines to date.

Based on these tests, Mr. Fedden claims the following advantages for the sleeve-valve engine as compared with the various poppet-valve types:

1 Total absence of maintenance except for spark plugs and magnetos.

2 Complete absence of any hot spot in the combustion chamber and better temperature gradients over the whole cylinder, reducing distortion and stresses.

3 Use of higher compression ratio with consequent decrease in fuel consumption or, alternatively, of higher boost pressures and greater bmep.

4 Complete enclosure of all working parts with no possibility of oil leakage from the cylinder end, and absence of external oil leads to working end of cylinder.

5 Greater effective valve areas and reduction of restrictions to the gas flow; better opening and closing diagrams, and improved volumetric efficiency.

6 More silent operation.

7 Freedom from hot lead corrosion as no parts of the cylinder reach temperatures which permit this corrosion and all, except the combustion space, are lubricated fully and continuously.

8 Cooler exhaust and, consequently, easier conditions for the exhaust manifold.

9 Centrally-situated spark plugs giving optimum effective running on single ignition where necessary.

10 Any desired control of cylinder turbulence with its possible application to stratified charges and abnormally weak mixtures, with gasoline injection. It is felt that this may be a profitable avenue of development as recent improvements in variable-pitch propellers and increases in compression ratios form an important argument in favor of fuel injection, whereas the experience now available with small high-speed Diesels has taught engineers that direct fuel injection with small quantities of fuel presents no insuperable difficulty. Fuel-air mixtures so arranged make it easier to determine over-all conditions of operation, while injection also allows the use of fuels which are not carburetable.

11 Extremely flat mixture loops permitting smooth running under conditions of extreme economy.

12 Smooth running due to the good combustion-chamber shape, to the more accurate and simpler valve timing, and to the elimination of cam, tappet, and valve wear.

13 Regular cylinder shape permitting the simplest form of pressure baffling.

14 Marked decrease in number of parts in any comparable size of engine, with consequent effect on production time and prices.

15 Relative simplicity of all major parts, permitting accurate repetition machining when properly tooled. It is considered that the possibilities of tooling this engine for a national emergency are considerably greater than with any other type of

equal efficiency which has been brought to the notice of the author.

16 Good accessibility and a clean exterior appearance.

17 Probability of considerably less trouble with resultant back pressure than on poppet-valve types when using an exhaust turbo-supercharger.

18 Greater freedom from cold corrosion. All surfaces wiped with oil, except the combustion chamber which is of simple form, with absence of pockets, and easily doped with any anti-lead corrosive medium for storage.

19 Greater reliability due to any of the causes just mentioned, and to the elimination of parts such as valve springs.

Diesel-Engine Indicator

OIL AND GAS POWER DIVISION, A.S.M.E., 1938 DALLAS MEETING

PRESENT-DAY Diesel engines, both the stationary and the marine type, present far more strenuous conditions for the operation of the indicator than those presented by the steam engine. These conditions are: high temperature, high pressure, rapid pressure rise, possibility of violent shocks, and the drying and somewhat corrosive effect of the combustion gases, necessitating frequent lubrication. After studying the problem for many years, K. J. DeJuhasz, member A.S.M.E., and associate professor of engineering research, The Pennsylvania State College, has developed and patented an indicator for use with Diesel engines, according to a paper presented by him at the meeting of the Oil and Gas Power Division, A.S.M.E., in Dallas, Texas, June 6 to 9. A description of the indicator, abstracted from the paper, follows:

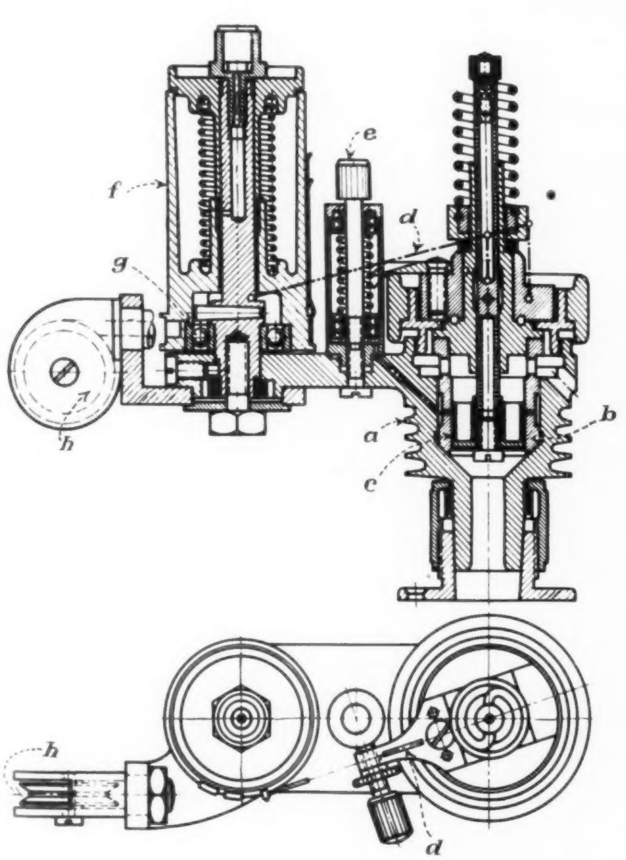


FIG. 6 DIESEL-ENGINE INDICATOR

Since the general arrangement and method of operation had to conform to that of the normal, pencil-type, external-helical-spring indicator, this precluded any radical departure from a standard type. Therefore, the new unit conforms to conservative design but embodies a number of detail improvements. The instrument is shown in Fig. 6. The main parts are the body *a*, cylinder *b*, piston *c*, pencil mechanism *d* with 7:1 magnification, pressure-feed lubricator *e* serving also as stop for the pencil mechanism, drum *f* of Bakelite (for lightness and rigidity) mounted on ball bearings *g*, and guide pulley *h* of Bakelite also mounted on ball bearings. The body is a rugged bronze casting provided with cooling fins in order to dissipate the heat and make the handling more comfortable. The pressure-measuring and recording elements, consisting of the cylinder head, piston rod, piston, cylinder, spring, and pencil mechanism, are mounted on the turntable. To assure accurate centering of the piston in the cylinder, both the piston rod and the cylinder are centered with respect to the cylinder head; thereby reducing friction, binding, and leakage. Inertia errors are reduced by making the piston rod short and hollow; buckling is prevented by the long guide in the cylinder head. The spring is of the well-tried double-wound helical type, working in tension, thus eliminating any buckling tendency.

The recording mechanism is of the Crosby type with a forked recording lever. The lubricator is mounted between the indicator cylinder and the drum post and can be filled with lubricant through a regular grease nipple fitting. The drum assembly consists of the drum post, spring, and drumhead, which can be removed as a unit from, or replaced into the outstanding arm of, the indicator body. Important advantages include a drum mass of about 30 per cent of that for a metal one of the same size, ball bearings which reduce friction and backlash due to wear, and the two keyways in the lower end of the drum post, either one of which can be made to engage with a locating pin in the body arm, depending on whether the drum is to be used as a right-hand or a left-hand instrument. The cord-pulley assembly consists of the pulley bracket (centered in the body and fastened to it with a bolt entering into the lower end of the drum post) and the pulley swivel rotatably mounted in the former.

It is the author's conclusion that satisfactory indicating of Diesel engines will make possible a solution of the problems which exist because of the increased reliability of indicator diagrams and data, leading to the further development of Diesel engines and their more satisfactory operation.

According to the author, the advantages and features which make this new instrument adaptable for high-speed and trouble-free operation can be summarized as follows: Low inertia of the pressure-measuring parts, attained by 7:1 magnification, short and hollow piston rod, short and light-weight springs, and a short recording lever with light pencil point; low inertia of drum parts, attained by the short Bakelite drum; suitability for use at high temperatures, attained by cooling ribs on indicator body and a pressure-feed lubricator for the piston with visible indication when lubricator is empty; and convenience and ease of handling and maintenance, attained by rugged construction, easy dismountability and interchangeability of cylinders and pistons, drum-spring tension adjustable without disturbing the drum, easy changeover from right-hand to left-hand operation, and use of ball bearings. It is the author's conclusion that this indicator will promote the solution of existing Diesel-engine problems, on account of the increased accuracy of indicator diagrams and data, further development of Diesel engines, and improve their performance.

LETTERS AND COMMENT

Brief Articles of Current Interest. Discussion of Papers in Previous Issues

Importance of Maintenance to Foundry Operation

To the Editor:

In his paper,[1] Mr. Bliss has touched on a subject too often neglected, and resulting in increased cost of operation, as he has brought out.

I think that probably the weakest link in foundry maintenance is the failure to anticipate trouble and thus avoid the actual shutdown which is so costly in lost production. Often this is due to neglect on the part of management in not providing adequate and capable help for the task. Too often the attitude is assumed that a certain number of breakdowns will occur regardless of precautions and, therefore, such emergencies will be met as they arise. The smart master mechanic will quickly spot the troublesome points on a new piece of equipment and make regular inspections, keeping a clerical record of wear and noises, and making notes on various conditions of the machine along with the inspection date. Such a program, however, can only be followed when he has ample help.

The whole maintenance job is more readily kept under control if all major equipment is listed along with serial numbers, speeds, data on connected motors, and records of parts replacement or repairs.

One point not discussed by Mr. Bliss is the system, used in some plants, of providing a compressed-air connection adjacent to all motors and machines for the purpose of blowing them off regularly. There has been some adverse criticism of this practice suggesting that the force of the compressed air carries particles of sand and grit into bearings and windings of motors, thus resulting in early trouble. At any rate care must be used in such work.

The remarks on insulation are most pertinent but I would interject a note of warning about insulation of high temperature. Some investigations tend to show that too-efficient insulation results in early failure of refractories due to "damming up" the heat. In so far as I know this occurs only at extreme temperatures.

A situation that should be corrected, to the mutual benefit of all concerned, is the lack of cooperation between the foundry and the equipment manufacturer. Often the manufacturer is criticized about weaknesses in design, and actual reports of failures are not properly made to him. In some instances the foundry provides its own spare parts or makes changes and the manufacturer continues to provide the same design not knowing that it is proving unsatisfactory in the field.

Mr. Bliss is to be congratulated on his able and timely presentation of a subject so pertinent to successful foundry operation.

C. R. Culling.[2]

[1] "Importance of Maintenance to Foundry Operation," by W. C. Bliss, Mechanical Engineering, June, 1938, pp. 489–490.

[2] Vice-President, Carondelet Foundry Company, St. Louis, Mo.

To the Editor:

Mr. Bliss has given an excellent picture of the extent of the mechanization trend in the modern foundry. In some plants maintenance becomes a major cost item, and the importance of proper organization for the work cannot be overemphasized. In too many foundry organizations, the maintenance department, particularly in these depression times, becomes a repair department and I want to reiterate and emphasize what Mr. Bliss has already said, "Experienced trouble shooters should be on hand at all times and make frequent inspections to detect wear that may result in trouble later on." "Catch a breakdown before it comes, and you will be money ahead."

Irrespective of the size of the plant there are five main divisions of a foundry maintenance department that must function if the plant is to continue to operate. These are engineering, operations, inspection, service, and record keeping, and they are all required, in some degree at least, in every maintenance department.

Under engineering come all matters of design, redesign, location, arrangement, installation, and in many cases, specification of equipment and such matters.

Under operations, I class the actual labor involved in the construction, destruction, repair, and maintenance of buildings and equipment.

Inspection takes care of routine and emergency inspection of equipment and buildings to see that the operating division functions properly.

The service division takes care of the sanitary and comfort facilities, yard maintenance, and the services such as electricity, gas, air, water, and heating. In many plants it also has charge of operating service departments such as overhead cranes and yard locomotives.

The record branch includes the provision for maintenance reports, spare-parts files, equipment lists, orders, and the like, and is frequently the most neglected section of the maintenance department. Whether maintenance is a one-man or a one-hundred-man job all of these five functions must be diligently handled, and if any one of them is slighted, delay and excessive cost will surely be reflected.

In addition to the maintenance of the mechanized equipment used for producing the foundry's output of castings, we are today forced to concern ourselves with the maintenance of good working conditions, to an extent not dreamed of even ten years ago.

The epidemic of silicosis-disability lawsuits, resulting in our present occupational-disease legislation, has made foundry operators extremely health-conscious.

Ventilation, sanitation, hygiene, and safety are problems of operation today. The maintenance of a plentiful supply of clean, dust-free air throughout the breathing zone in the shop is a major responsibility of the maintenance department. The great strides made in recent years by foundry-equipment manufacturers in enclosing and exhausting dust-creating operations has made it possible to maintain throughout the shop satisfactory air conditions in respect to health hazards. The development of wet-type dust collectors has made possible the effective collection of hot and moist dusts, which were troublesome to handle in a dry-type collector.

General heating, adequate day lighting, proper artificial lighting, dust re-

moval and collection, mechanical ventilation, sanitation and hygiene, and properly supervised safety procedures are all being given much more attention today than formerly, and are all effective in the maintenance of the proper working conditions necessary for optimum productive effort.

L. E. EVERETT.[3]

TO THE EDITOR:

Mr. Bliss has presented an excellent paper outlining the general requirements for mechanical equipment in the foundry, and while his observations are particularly concerned with steel-foundry problems, these same problems are true of all foundries. I agree heartily with all he has said.

Due to the nature of operation in a foundry, a shutdown of primary mechanical equipment is apt to be very costly, and a breakdown, in many cases, disastrous. The only safeguards against such happenings are exceptionally sturdy equipment of simple proved design, and unceasing inspection and maintenance.

Simple forms of construction and mechanical design, because of their reliability, are preferable to more complicated, even though more efficient, designs which may be less sturdy.

With few exceptions, most foundries are old structures and, in the original planning, provision was not made for mechanical equipment now installed or being installed. In selecting equipment for such shops care must be taken to see that it fits all conditions and that it can be properly inspected and maintained as located. I have in mind a foundry in which an installation of cranes was made as a unit in an old structure. When repairs had to be made and an armature changed in an emergency, it was necessary either to knock out a portion of the outside wall of the building or take the crane down to make the repairs.

In regard to the problem of lubrication, I have found that undue wear, particularly of bearing surfaces, is not caused so much by neglect of lubrication servicing as by a faulty system of lubrication on the machines. Such machines are constantly exposed to sand and grit, and a lubrication system should be designed to eliminate this material as much as possible. In some cases it has been found best to operate bearings dry, as there was less wear in this condition than when oil or grease was used, on which grit and other grinding media collected. Where dust-proof bearings cannot be applied we have found that a grease bearing is much more satisfactory than an oil bearing because, with the application of new grease from a covered reservoir, the old grease with the grit that it is carrying, is forced out.

In recent years machine designers have given particular attention to the practical maintenance of equipment they are offering the foundries, and because of this I feel that with all equipment being offered today, as well as that which will be offered in the future, our problems of maintenance will be fewer and less serious than in the past.

G. W. MITSCH.[4]

TO THE EDITOR:

Mr. Bliss has presented an interesting review of the importance of anticipating, correcting, and maintaining the mechanical features of the typical foundry. One must ever be alert in planning the adoption of improved methods of production and providing means for the maintenance of such equipment. These comments augment the author's statements.

Lubrication is not the problem that it was several years ago. Pressure grease systems whereby grease is forced into the center of the bearing have corrected the excessive wearing of bearing surfaces due to the conditions mentioned by the author. The initial cost of these systems is more than offset by the lower maintenance charges. Even on some heat-treating furnaces where proper lubrication must be obtained on warm or hot bearing surfaces, pressure grease systems with as high as 1000 lb pressure and as many as 100 outlets are employed satisfactorily. All large machine tools have pressure systems and some have in addition, sight-feed oilers.

The electrical manufacturers have been alert to the lubrication problem and, by furnishing ball-bearing motors, have greatly reduced maintenance troubles.

One hard problem is the proper lubrication of crane track-wheel bearings. The greatest difficulty in this respect has been overlubricating and the carrying of excessive oil and grease onto the crane runways. Every known method by the use of felt, wool waste, and various spring-type oilers, has been tried, but none has proved a satisfactory solution.

In foundries the use of fully automatic equipment has not proved entirely satisfactory. Advanced automatic features in the mechanization of foundry, molding, and annealing equipment do not always justify by their savings the cost of their installation and maintenance. The added features require carrying of additional spare parts and increasing of the repair forces so that expected savings are reduced.

In former years, equipment breakdowns were not considered of as great importance as they are at the present time where constant service and the maintenance of production schedule require equipment to operate consistently. The limitation on working hours and the penalty of increased rates for overtime require the production departments to run smoothly at all times. This involves constant supervision and thorough inspection of equipment so that changes and repairs can be anticipated and unit parts replaced before a delay occurs. This better-inspection requirement should work to reduce the number of spare parts required to be held available.

It is advisable to carry only as large a stock of spare parts as is needed. In former years, the tendency was to go to the extreme for protection but nowadays, with many ingenious mechanical features being developed, it is well to keep the supply of spare parts at a minimum and, perhaps, look forward to replacing machinery at regular intervals with newer and more modern equipment.

In connection with the conveying of sand, the vibrator conveyer shows considerable promise. As this unit eliminates the belt which is subjected to the hot sand, its cost of operation is low and it can also be regulated in a few minutes from practically no flow to full capacity.

Present-day tolerances necessitate the use of core machines, of which many satisfactory types are available.

In the shotblasting of steel castings, the tendency is to keep the operator out of the blasting area and to do the cleaning, without the blast operator's directing the abrasive stream, by locating the casting to be cleaned in a definite position on a conveyer and passing it through an area of directed shot.

The accessibility of equipment for repairs and the proper training of the repair personnel are essential for a smoothly run shop.

JOHN W. PORTER.[5]

TO THE EDITOR:

In my paper I endeavored to bring out certain basic principles rather than a detailed account of various repair problems. The examples given were a few cases where we made improvements on the equipment as furnished and thereby bettered operation and decreased mainte-

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[4] Assistant Manager of Foundries, American Car and Foundry Company, St. Louis, Mo.

[5] Assistant Works Manager, American Steel Foundries, Granite City, Ill.

nance cost. No doubt the manufacturers of this equipment have recognized the faults and made similar changes in the equipment they furnish.

I quite agree with Mr. Culling as to the importance of equipment manufacturers keeping in touch with the firms using their product. After all, the foundry is the proving ground and much can be learned to better the operation and maintenance of their machines by checking up.

Insulation is important but must be applied with care by someone who is thoroughly familiar with the results which will be obtained.

The organization and records of the maintenance force must function for the best results. Too often records are neglected causing a serious delay when they are needed most. Changes in the personnel are less serious if complete records are maintained. Mr. Everett has outlined a splendid maintenance-department setup for any foundry, large or small.

The proper protection of the employees by the installation of suitable dust-collecting devices will pay dividends.

Mr. Mitsch has been confronted with the problem almost everyone meets who installs equipment—the installation of new equipment in an old building. Loads should be carefully checked and the strength of columns and trusses looked into to eliminate the possibility of a costly failure.

Lubrication has made wonderful strides in the last ten years and improvements are being made every day. Roller bearings and ball bearings when properly protected far outlast the old type of bearing and save the cost of many replacements. Mr. Porter has made a valuable addition to my paper in his discussion.

WILLIAM C. BLISS.[6]

Smoke Abatement

TO THE EDITOR:

Mr. Tucker has brought us up to date on the efforts that have been made to provide cleaner air for his city.[7] He is to be most heartily commended for the way in which he has taken hold of what is, to put it in mildest form, a difficult job.

Departing from his text and at the risk of being accused of heresy, I want to say that smoke abatement (which is one part of the broader field of air hygiene) is much more than an engineering problem. True, the engineer must provide the equipment, see that proper fuel is available, and prescribe the method of operation. But in the broad sense, this problem is one of human relations, with chemical, physical, psychological, physiological, and even pathological phases that are not within the experience of the average engineer. Therefore, though holding an engineer's degree, and realizing that a competent engineer is a necessary part of the staff, I have been opposed to the general idea that only an engineer can qualify to operate an antismoke ordinance. While appreciating to the full the splendid work which has been done and is being done by smoke-abatement engineers in charge of municipal bureaus, I feel that exclusion from such responsible positions of other scientists, though they may be broadly trained and widely experienced, tends to build around the bureau a barrier that may keep its activities within a too-narrow field.

Committees that formulate model ordinances usually are made up of engineers, largely men of experience in power-plant operation. In such a group municipal smoke-abatement officials constitute a small minority, and the natural consideration of the matter is upon the basis of currently available fuel-burning equipment and fuels.

What is the result? The power-plant engineer, knowing that his plant can operate cleanly, in all sincerity is inclined to oppose drastic rules. He doesn't need them. The engineer in the fuel-burning equipment field wants regulations based on what boilers and furnaces can be shown to do on the test floor, without proper allowance for the type of operation that may be expected in practice; in other words, he wants to assume that there will be competent firemen who will in all cases operate the boilers as they should be operated. The enforcement officer is inclined to recognize these viewpoints, although he knows that his is the difficult task of securing, with an inadequate staff, compliance with the law.

In the ordinary antismoke ordinance, requirements are the same for power plants and heating plants, for large office buildings and private homes, if private homes are regulated at all. At the one extreme there is the well-equipped plant operated under continuous engineering supervision; at the other the small plant, not designed to burn a potentially smoky fuel, in which is used low-priced but highly volatile coal, fired under conditions that make complete combustion impossible; the result is a nuisance in the community and a headache for the smoke-abatement officer. Surely it is fair that restriction and supervision be based somewhat on the probability of what will occur under characteristic operating conditions.

I am in agreement with Mr. Tucker that something must be done about this. Close official supervision is economically impracticable. The alternative (for any class of fuel burners) is to allow a choice between equipment that, with the fuel desired, will not smoke, and the required use of a fuel that cannot smoke.

If we think of air-pollution prevention as a problem in human relations, and of engineering as a necessary tool, it narrows down pretty much to a question of how far any individual or group or class may be permitted exemption from regulation in practices that injure the community aesthetically, economically, or in its health.

This may seem somewhat afield from the particular points under discussion, but is it not possible that in the past we have had too-narrow an outlook and that our progress in smoke abatement consequently has been slower than necessary.

H. B. MELLER.[8]

TO THE EDITOR:

Mr. Tucker is to be congratulated on his presentation of the subject. It is certainly true that regardless of all that has been written and said regarding the smoke problem, it still exists and many engineers have an indifferent attitude toward it. If consulting engineers and engineers connected with plants would take an active interest in the problem, the amount of smoke emitted into the atmosphere would be reduced with economy to the fuel user.

In smoke-abatement work it is essential that large and domestic heating plants as well as railroads, floating equipment, and large commercial plants be controlled under an effective ordinance creating a department of smoke regulation with no division of responsibility. Any smoke department to be effective must keep up with the times and be able to advance new and novel steps to produce results.

Such a department is the one in St. Louis, with its solid-fuel control. Fuel control will certainly be a contributing factor to less smoke in a city like St. Louis, but a problem of solid-fuel control would not exist in most other cities in the United States.

It is strange that plant operators must be forced to do what they should want

[6] Works Manager, Scullin Steel Company, St. Louis, Mo. Mem. A.S.M.E.

[7] "Smoke Abatement," by R. R. Tucker, MECHANICAL ENGINEERING, May, 1938, pp. 377–380.

[8] Managing Director, Air Hygiene Foundation, Pittsburgh, Pa., Chief, Bureau of Smoke Regulation, Dept. of Health, Pittsburgh, Pa.

to do for economy of operation. When they know they are being watched, the plants do not smoke and are consequently more efficiently operated. Therefore, it is certainly important that a smoke-regulation department impress the operators with the fact that they are being constantly watched.

Time and experience will develop improvement in smoke-abatement administration. The wholehearted cooperation of the small fuel user should be gradually obtained by a constantly repeated educational process. This is just as important for the increased effectiveness of smoke abatement as the cooperation of the large fuel user. It is also true that legislative acts alone will not and cannot control the emission of smoke.

JOHN L. HODGES.[9]

TO THE EDITOR:

There is today, greater interest than ever in eliminating atmospheric pollution. The public is concerned about the effects on health as well as the damage to property, the dirt, and the nuisance. Research conducted in the last few years at the Mellon Institute, Pittsburgh, and at the Oscar Johnson Institute in St. Louis, shows conclusively that smoke has a detrimental effect on health. There is a more insistent demand than ever that something be done.

This is the engineers' responsibility, especially mechanical engineers. The elimination of the discharge of smoke, solids, and deleterious gases is a highly technical problem. On the other hand, it is a very human problem. It is appropriate that the A.S.M.E. Fuels Division arranged smoke-abatement sessions when the Society held its Semi-Annual Meeting in St. Louis, this spring. Whether warranted or not, St. Louis has the reputation of being the smokiest city in the United States. No surveys have been made on a comparable basis so that this is largely a matter of opinion. There is not much doubt that bad smoke conditions in St. Louis have seriously affected real-estate values. St. Louis probably has the most difficult smoke problem in the country. It is located practically on top of a large bituminous-coal field; this coal has high-volatile, high-ash, and high-sulphur content. The new St. Louis Smoke Ordinance has some unusual features. This is the first time there has been any legislation regulating the ash and sulphur content of coal sold in a community. Commissioner Tucker is tackling the problem in an intelligent manner and has a wonderful opportunity to do a constructive piece of work.

Let us consider briefly, the various classes of plants:

First: Railroads. Elimination of railroad smoke is largely a question of supervision and modernization of equipment. In Hudson County, N. J., railroad smoke density this year is running below one per cent. This shows what can be accomplished.

Second: Large Industrial Plants and Central Stations. Such plants have a good staff of engineers and up-to-date equipment. Smoke from such plants is generally easily controlled.

Third: Small Industrial Plants. This is much more of a human problem. It is more difficult to get good equipment installed. Such plants make much more work for a smoke department, but, nevertheless, it is a question of supervision and a good system of permits and certificates.

Fourth: Floating Equipment. Like the railroads, this is largely a question of supervision and the right kind of equipment.

Fifth: Large Heating Plants, including apartments, office buildings, and institutions. This class of plants requires more work and the smoke is harder to control. This is due to a number of causes, including ignorance and indifference of owners and operators. Also, poorer supervision than in industrial plants. Mechanical firing equipment is available and its installation means an economy in fuel. Strenuous work by a smoke commissioner and his staff will get results.

Sixth: Small Heating Plants, including residences, stores, flats, garages. A survey made in St. Louis ten years ago by the Citizens' Smoke Abatement League, showed that 35 per cent of the total smoke came from these small plants. Mr. Tucker has said that there are 140,000 buildings in St. Louis. His survey to date shows that 38 per cent of them are heated with stoves. He and his eight inspectors cannot possibly cover the vast number of small plants. In my opinion it is hopeless to eliminate smoke from this source by teaching firing methods. There are only two real solutions to this part of the problem, first, installation of mechanical firing equipment; second, use of smokeless fuel. By "smokeless fuel" I mean anthracite, coke, or gas and not the so-called "smokeless coal"

Section 18 of the new St. Louis Smoke Ordinance, about which we have heard so much, was not intended to eliminate smoke. Its purpose was to reduce the discharge of fly ash and sulphur gases. It is the first step in the solution of the St. Louis smoke problem.

As I have said on previous occasions, one great trouble with smoke elimination is that we are inclined to think of it in terms which are too small. It is a major community problem and should be considered as such. In far too many cases there has been "bally-hoo" for a few years and then a let-down in the effort with the feeling that the problem is solved. St. Louis is an excellent example. Some good work was done by former smoke commissioners and by the Smoke Abatement League. A few years ago the smoke-abatement work was practically discontinued. Within a short time smoke was worse than ever. Diligence is the price of success. There must be continuous effort and constant supervision.

WILLIAM G. CHRISTY.[10]

[When Mr. Tucker's paper was published in the May issue of MECHANICAL ENGINEERING a footnote was inadvertently omitted which read: "The information regarding the past ordinances of the City of St. Louis from 1864 to 1924 was obtained from "Study of Police Power as Embodied in Laws, Ordinances, and Court Decisions," by Lucius H. Cannon."—EDITOR.]

Methods of Flue-Gas Analysis

TO THE EDITOR:

It seems interesting that the subject of methods of flue-gas analysis with particular respect to unburned hydrogen, hydrocarbons, and carbon monoxide should be the subject of discussion as outlined by W. S. Cooper in his letter under the heading, "Measuring Composition of Flue Gas" in the October issue of MECHANICAL ENGINEERING.

Little need be said concerning the tremendous amount of discouragement which manufacturers of thermal-conductivity gas-analysis apparatus have had during the last fifteen years. This discouragement was based on an attitude taken by various operating engineers that the thermal-conductivity method of flue-gas analysis was inaccurate because the reading as produced by the instrument may have indicated as much as 5 and 6 per cent lower than the Orsat which was used to check the installation.

Hydrogen, having a thermal conductivity approximately fourteen times greater than carbon dioxide, would cause

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[10] Smoke Abatement Engineer, Hudson County, N. J. Mem. A.S.M.E.

instruments to read in a negative direction; hence there was a condition where a trace of hydrogen prevalent in flue gas (in spite of the fact that a fairly high percentage of carbon dioxide was being maintained), would cause the instrument to read low. Possibly the manufacturers of thermal-conductivity-analysis apparatus could have avoided all of this difficulty by graduating the scale in terms of "excess air" instead of carbon dioxide, thereby taking advantage of the readings which accurately portrayed on a thermal-conductivity analyzer what was going on within the combustion chamber.

It would not be amiss to review again the article published by A. H. Senner in the November, 1936, issue of MECHANICAL ENGINEERING under the title, "Domestic Oil Burners." In this article, the writer clearly portrays why the simple Orsat cannot be used successfully in making analysis of flue gases in domestic oil-burner installations. While we can hardly compare the efficiencies of domestic installations with those found in industry, there is a greater possibility of finding aggravated conditions caused by insufficient combustion space or too large a combustion space, and the well-known "bugbear" of insufficient flue-gas travel. The article deals with oil burners, but the same conditions apply in the burning of solid fuels.

Possibly, in the future a greater amount of valuable, interpretative study can be made when the engineering field at large fully appreciates that in continuous analysis lies hidden many secrets which heretofore have been surmised, but not fully appreciated. Thermal conductivity, density, or specific-gravity analysis instruments will unquestionably play an important part in these studies because all of them are affected by the presence of hydrogen when they are calibrated for the measurement of carbon dioxide in a mixture of oxygen and nitrogen. Possibly instead of rejecting the feasibility of using these methods of measurement because they have an inherent error of being affected by hydrogen, we will ultimately take advantage of this inherent error and consider it part of an instrument calibration.

WM. O. HEBLER.[11]

A Correction

In Fig. 1 of W. K. Adkins' paper "Industrial-Evaporator Design, Application, and Operation," page 738 of the October, 1938, issue of MECHANICAL ENGINEERING, the outlet temperature from the evaporator drip cooler should be 257 F and not 275 F.

[11] President, Wm. O. Hebler Company, Newark, N. J. Formerly General Manager of Charles Englehard, Inc. Mem. A.S.M.E.

REVIEWS OF BOOKS

And Notes on Books Received in the Engineering Societies Library

Fluid Mechanics for Hydraulic Engineers

FLUID MECHANICS FOR HYDRAULIC ENGINEERS. By Hunter Rouse, Assistant Professor of Fluid Mechanics, California Institute of Technology. Engineering Societies Monographs, McGraw-Hill Book Co., Inc., New York, N. Y., 1938. Cloth, 6 × 9 in., 422 pp., illus., $5. Introductory price to members of engineering societies, $4.

REVIEWED BY LEWIS F. MOODY[1]

THE mathematical theories of fluid flow, as presented for example in that ponderous work Lamb's "Hydrodynamics," have long been a source of vexation to the hydraulic engineer. The engineer recognizes the empirical character of much of his hydraulic knowledge and the need of a more rational and unifying basis; but when he attempts to apply the potential theory, the method of flow networks, and other developments of mathematical hydrodynamics to actual hydraulic problems, the many striking contradictions of facts of observation leave him skeptical and perplexed as to means of reconciliation. As Professor Rouse remarks in the preface to this new book: "The hydraulic engineer...has as yet had few conclusive proofs that his methods might be bettered by subordinating empirical formulas to more rational methods of attack."

The renaissance of hydrodynamics or fluid mechanics in recent years has already resulted in overcoming some of the earlier difficulties, but many questions still await solution and integration. While it has already had fruitful application in the aerodynamic field, its possibilities of application to hydraulic engineering have been developed to only a limited degree.

This new work of Professor Rouse is the latest of the "Engineering Societies Monographs" sponsored by four national engineering societies. It is a timely and useful addition to our literature, outlining in a single volume the basis of treatment of potential flow, flow networks, the equations of Euler; modified theory considering viscosity; new developments by Prandtl, von Kármán, and others on the boundary layer, turbulence, fluid friction; and applications to special fields.

Although it successfully achieves simplicity in its mathematical derivations, and should be clear to the engineer or graduate with good mathematical grounding, the book should not be used to replace a thorough course in elementary hydraulics, which is a prerequisite for any student taking it up. Indeed the writer disagrees with the recent vogue for substituting fluid mechanics for our college courses in hydraulics. As Professor Rouse remarks in his preface: ". . . many of the leading technical schools are gradually replacing elementary hydraulics courses with instruction in general fluid mechanics, while a number of excellent textbooks on the subject are available in the English language. Nevertheless, existing texts beyond the elementary class are intended primarily for the student of aeronautics, and the hydraulic engineer will find in them little of direct application to his own field of endeavor."

The book should be read as a whole. The engineer should be warned against applying detached sections. For example, the method of plotting flow nets given in chapter 2 is based on the assumptions of negligible energy loss, the

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existence of irrotational, nonviscous, and nonturbulent flow, and the adherence of the flow to fixed boundaries. One of the applications, to flow in an elbow, is later specifically invalidated when "separation" is discussed; and the chapters on turbulence and the boundary layer will vitally affect the range of application of these classical methods. The writer questions the author's own use of the Bernoulli formula in the last part of the section on cavitation, without including any term for loss of head.

The limitations inherent in the assumptions of the classical theory are duly recognized. For example the consequence of the theory of potential flow requiring at certain points infinite velocity and infinitely negative pressure intensity is mentioned with the statement that: "Such conditions are mathematically possible in potential flow, but since they are physically quite out of the question, it is evident that the flow net cannot possibly describe the actual state of motion past such a boundary." After extending the Eulerian equations to include viscous forces in the Navier-Stokes equations it is pointed out that "not only are the Navier-Stokes equations of more complex form than those of Euler, but...irrotational motion of a viscous fluid is generally out of the question unless fluid and boundaries move bodily through space." Also when turbulence is taken up in chapter 9 it is noted that "the preceding chapter dealt with cases of predominant viscous action . . .; on the other hand, the entire first part of this book proceeded on the assumption that viscous action was nonexistent . . . . Between these two limits of the realm of fluid motion there lies a vast range of problems in which neither dynamic nor viscous effects can be ignored. It is here that the majority of engineering problems are to be found."

In addition to the subjects mentioned previously part one includes a brief outline of the application of dimensional analysis and a chapter on the use of complex variables and conformal representation, illustrated by the development of the Kutta and Joukowski profiles. It properly includes a section on cavitation, which might well have been extended, on account of its importance to the engineer, to include for example the Thoma formula. An important and enlightening section on separation then follows.

Part two takes up viscous forces, laminar flow, turbulence, the boundary layer, and flow around stationary bodies. It then contains a valuable chapter on pipe friction outlining the Prandtl-von Kármán developments and putting the conclusions in usable shape. Then follows an extensive chapter on nonuniform flow in open channels along the general lines used by Professor Bakhmeteff; and finally a chapter on sediment transportation. Part three is devoted to the theory of wave motion and gravity waves in open channels. It contains little on the subject of water hammer, an extensive field in itself.

As a minor suggestion the addition of a reference table of the symbols used would have been helpful, as well as a collection of the references in a bibliography.

The author has made excellent use of the material gained as a Freeman scholar and subsequently, as he mentions in his preface, in his association with Professor Rehbock, Professor Spannhake, Professor Bakhmeteff and Dr. von Kármán; and has produced an interesting and useful book.

Combustion, Flames, and Explosions of Gases

Combustion, Flames, and Explosions of Gases. By Bernard Lewis and Guenther von Elbe. The Macmillan Company, New York, 1938. Cloth, $5^1/_4 \times 8^1/_2$ in., 415 pp., 79 figs., $5.50.

Reviewed by R. A. Sherman[2]

This book is designed by the authors to coordinate and appraise critically the voluminous literature on combustion phenomena. They are well-qualified for the task. Both physical chemists—Lewis is with the Central Experiment Station of the Bureau of Mines at Pittsburgh and von Elbe with the Coal Research Laboratory of Carnegie Institute of Technology. During the past several years they have collaborated on problems of mutual interest and many papers have appeared under their joint authorship.

The presentation is divided into four parts: (1) Chemistry and kinetics of the reactions between fuel gases and oxygen, (2) the propagation of flames, (3) the state of the burnt gas, and (4) problems in the technical combustion process.

As indicated by the subjects of the subdivisions, three of the four parts are concerned with the fundamental theory of combustion of gases. The engineer who has long considered that combustion was a simple process of the combination of carbon and hydrogen with oxygen to form carbon dioxide and water will find that many intermediate reactions occur. The combustion of hydrogen involves the formation of atoms of H and O and the radical OH and the combustion of the hydrocarbons naturally involves many more complex intermediate reactions. Many of these are yet incompletely understood but the authors present their conclusions as to the best available evidence.

Part 2 on the propagation of flames reviews the extensive experimental research on limits of inflammability and on the velocity of flame propagation in both spherical and stationary flames. The authors cite the limitations of the experimental methods that have been used. The investigation of spherical flames in soap bubbles is limited to moist mixtures and the results in constant-volume vessels are affected by the contact with the walls. The determinations of burning velocities of stationary flames by the Bunsen-burner method are subject to error because of the dilution of the flame by secondary air at the base.

Lewis and von Elbe state that the problem of the propagation of the reaction zone through a combustible mixture is one of the most complicated in the whole field of combustion and conclude that the weakness in past treatments is the concept of the ignition temperature as a true physical constant of the gas mixture. This concept they refuse to accept. They propose the hypothesis that the thermal and chemical energy per unit mass in any elemental layer between the unburnt and burnt gas is constant and analyze the flow of chemical energy transported through the reaction zone by mass flow. An example of the application of this hypothesis to burning mixtures of ozone and oxygen shows that although the absolute agreement is far from satisfactory, there is agreement in order of magnitude between experimental and calculated velocities.

On the other hand, the theory of diffusion flames, which are those where combustion occurs at the boundary between a layer of gas and a layer of air, has been well developed by Burke and Schumann whose theory, presented in 1928, forms the basis of the chapter on this subject.

A thorough treatment of the detonation of gaseous mixtures in chapter 14 includes a collection of excellent photographs of detonation waves obtained by various workers.

Part 3 on the state of the burnt gas is introduced by a chapter on band spectroscopy followed by chapters on explosions in spherical vessels, on freely expanding

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spherical flames, and on the temperature and radiation of the burnt gas. The last chapter in which the work of Hottel and his colleagues, much of which has been presented before the Society, is cited, will be of the greatest interest to the engineer.

The engineering application of the theory covered in the book is made in part 4 which covers but 29 of the 415 pages. Only two pages are devoted to industrial heating which, the authors say, is clearly outside the scope of their book. They refer to a number of books and papers for the engineering application. Combustion in the internal-combustion engine including both the Otto and Diesel cycles is quite fully discussed with extended reference to knocking and the characteristics of fuels.

In three appendixes are given tabulations of authoritative data on energy contents of gases, equilibrium constants of reactions, heats of combustion, limits of inflammability, and experimentally determined flame temperatures.

Although the application to engineering problems in combustion remains to be done by the reader or by the author of another book, the book is clearly valuable to the worker in fundamental research in gaseous combustion.

Books Received in Library

About Petroleum. By J. G. Crowther. Oxford University Press, London, New York, Toronto, 1938. Cloth, 6 × 9 in., 181 pp., illus., diagrams, $2.25. A simple description of the petroleum industry, intended for those who are curious about what petroleum is, where it comes from, how it is produced, and how it is transformed into the familiar commercial products. Such special phases as geophysical prospecting and knock phenomena in engines are briefly treated.

Advanced Mathematics for Engineers. By H. W. Reddick and F. H. Miller. John Wiley & Sons, New York, 1938. Cloth 6 × 9 in., 473 pp., diagrams, charts, tables, $4. Differential equations, vector analysis, probability, operational calculus, and the more complex mathematical functions and series are discussed, emphasis being placed on physical applications by illustrating each principal topic by problems relating to civil, electrical, mechanical, and chemical engineering. Definitions, physical laws, theorems, and physical units are presented with particular care.

Air Conditioning. By C. A. Fuller with collaboration of D. Snow. Norman W. Henley Publishing Co., New York, 1938. Cloth, 6 × 9 in., 577 pp., illus., diagrams, charts, tables, $4. In addition to the customary information concerning thermodynamic fundamentals, design of distributing equipment, principles of condensers, evaporators, etc., and descriptions of installations, the subject of codes and ordinances covering air conditioning is discussed. The nontechnically trained reader has been primarily considered.

Airplane Design. By K. D. Wood. Third edition, June, 1938, published by the author at Purdue University, Lafayette, Ind., distributed by the Cornell Co-Op Society, Ithaca, N. Y. Paper, 9 × 11 in., illus., diagrams, charts, tables, $4. A textbook of airplane layout and stress-analysis calculations with particular emphasis on economics of design. Load factors, materials, costs, and drafting procedure are discussed, as well as the actual work of technical design for the various component parts. Appendixes contain design data for practical work.

Applied Mechanics. By H. F. Girvin. International Textbook Co., Scranton, Pa., 1938. Cloth, 6 × 9 in., 336 pp., diagrams, tables, $3. A comprehensive treatment of the subject, containing a large number of descriptive problems. The material has been so arranged that the chapters covering graphical solutions may be used as a text for a course in graphic statics, being segregated from the purely mathematical treatment.

ATM (Archiv für technisches Messen), Lieferungen 81–83, March, April, May, R. Oldenbourg, Munich and Berlin, 1938. Paper, 9 × 12 in., illus., diagrams, charts, tables, 1.50 rm. each. Three numbers of a monthly publication containing classified articles covering various types of apparatus and methods for technical measurements. Certain ones also contain descriptions of specific instruments which are manufactured by German companies.

Bauelemente der Feinmechanik. By O. Richter and R. v. Voss, with the aid of F. Kozer. Second edition. V.D.I. Verlag, Berlin, 1938. Leather, 7 × 10 in., 491 pp., diagrams, charts, tables, 25 rm. This treatise aims to supply makers of scientific instruments and other fine mechanisms with information concerning the structural elements of these products, to which slight attention is usually given in books on mechanisms. A large amount of practical information is supplied upon driving mechanisms, couplings, speed regulators, bearings, etc. The new edition has been thoroughly revised and rewritten.

Bibliography on Industrial Radiography. (Document 1139.) By H. R. Isenburger. American Documentation Institute, Washington, D. C., 1938. Typewritten, 52 pp., 9 × 12 in., paper, $0.72 in microfilm, or $3.32 in black and white prints. This supplement to St. John and Isenburger's book, "Industrial Radiography," contains 776 references, arranged chronologically and covering material from early eighteenth-century general theory to the most recent 1938 applications.

Davison's Textile Blue Book, United States, Canada, and Mexico. Handy edition, seventy-third year, July, 1938, to July, 1939. Davison Publishing Co., Ridgewood, N. J., 1938. Cloth, 5 × 8 in., 1234 pp., maps, $5. An annual publication containing lists of manufacturers of cotton, rayon, silk, and knit goods, and of dyers and finishers, geographically arranged. Commission merchants, dealers, and importers are listed, also domestic and foreign raw-cotton firms, cotton compresses, and warehouses. Two special lists cover pertinent associations and railroads serving the various mills.

Demonstration Experiments in Physics. Edited by R. M. Sutton, prepared under the auspices of the American Association of Physics Teachers. McGraw-Hill Book Co., New York and London, 1938. Cloth, 6 × 9 in., 545 pp., illus., diagrams, charts, tables, $4.50. This is a collection of nearly twelve hundred lecture experiments for the use of high-school and college teachers of physics and general science. The book was prepared under the auspices of the American Association of Physics Teachers, and includes contributions from two hundred physicists. The descriptions of experiments are direct and emphasis has been placed upon simplicity of apparatus and procedure.

Deutsche Kraftfahrtforschungen, Hefte 4–8. V.D.I. Verlag, Berlin, 1938. Paper, 8 × 12 in., illus., diagrams, charts, tables. Heft 4, 47 pp., 5 rm. Heft 5, 20 pp., 2 rm. Heft 6, 8 pp., 1 rm. Heft 7, 21 pp., 2.25 rm. Heft 8, 4 pp., .75 rm. This series contains accounts of various investigations in the field of automobile engineering, undertaken at the request of the German Ministry of Transport. No. 4 includes a study of connecting-rod lubrication by fresh oil, a summary of experiments with Diesel engines, and a description of a new photocell indicator for investigating radiation from engine combustion chambers; No. 5, a study of combustion in high-speed Diesel engines; No. 6, transverse fractures of cardan shafts; No. 7, selective solvents for producing Diesel fuels from lignite tars; No. 8, signaling overtaken vehicles.

Diesel Engines. By B. J. von Bongart. D. Van Nostrand Co., New York, 1938. Cloth, 6 × 10 in., 335 pp., illus., diagrams, charts, tables, $5.50. Primarily designed as a text for the study of internal-combustion engines of the compression-ignition type, this book covers general principles, the customary equipment, and the various types of engines within this field. There are also embodied the results of certain researches by the author and others on particular problems in Diesel engineering.

Eignung von Vorwärmern und Kühlern im Kraft- und Wärmebetrieb, edited by Arbeitsgemeinschaft Deutscher Kraft- und Wärmeingenieure (ADK) des V.D.I. V.D.I. Verlag, Berlin, 1938. Paper, 6 × 8 in., 59 pp., illus., diagrams, charts, tables, 4 rm. This booklet discusses the various types of surface condensers, heat exchangers, oil coolers, generator air-coolers, and hot-steam coolers. The uses, requirements, and capabilities of each type are described, examples of construction explained, and materials and operating experience given. The work is intended to facilitate the selection of the most suitable devices for any need.

Electromagnetics. By A. O'Rahilly, with a foreword by A. W. Conway. Longmans, Green & Co., London, New York, and Toronto, 1938. Cloth, 6 × 9 in., 884 pp., diagrams, tables, $12.50. A critical review of the classical theory of electricity, discussing fundamentals, and the work of the men who have had an important influence on the thought and action in this field of physics. At the end of this comprehensive survey appear two chapters in which a radical exposition of the meaning of the symbols of physics is worked out and the question of basic units and dimensions is treated. There is a large bibliography.

Elements of Ferrous Metallurgy. By J. L. Rosenholtz and J. F. Oesterle. Second edition. John Wiley & Sons, New York, 1938. Cloth, 6 × 9 in., 258 pp., illus., diagrams, charts, tables, $3. A general elementary treatment for students not specializing in metallurgy. Blast-furnace practice, steel-making processes, heat-treatment, the structure and working of various steels, and iron-foundry work are treated concisely and clearly.

ELEMENTS OF ORDNANCE, prepared under the direction of Lt. Col. T. J. Hayes. John Wiley & Sons, New York, 1938. Cloth, 6 × 9 in., 715 pp., illus., diagrams, charts, tables, $6.50. This textbook, intended for use at West Point, is essentially a revision of McFarland's "Textbook of Ordnance and Gunnery." It aims to give the student a broad foundation, upon which further technical studies can be based.

ENGINEERING MECHANICS. By S. Fairman and C. S. Cutshall. John Wiley & Sons, New York, 1938. Cloth, 6 × 9 in., 267 pp., diagrams, tables, $2.75. The object of this elementary text is to present only as much material as can be conveniently covered in the time available for a basic course. Topics covered in prerequisite courses and material which may be deferred to more advanced courses are consequently omitted. Otherwise the book contains the customary treatment of statics and kinetics. There are numerous problems included in the volume.

ENGINEERING TERMINOLOGY, Definitions of Technical Words and Phrases. By V. J. Brown and D. G. Runner. Gillette Publishing Co., Chicago, 1938. Cloth, 6 × 9 in., 310 pp., illus., diagrams, $3.50. A list of terms often used in technical writing and specifications, with definitions obtained from the usage of various trade and engineering organizations. The terms apply especially to civil engineering and architecture. In addition the book contains a concise Spanish-English and English-Spanish dictionary of highway terms, a brief German-English dictionary of terms for mineral aggregates and several tables of technical symbols, abbreviations, conversion factors, etc.

FARM GAS ENGINES AND TRACTORS. By F. R. Jones. Second edition. McGraw-Hill Book Co., New York and London, 1938. Cloth, 6 × 9 in., 486 pp., illus., diagrams, charts, tables, $3.75. The first part of this text deals with the fundamentals involved in the construction and operation of the simple internal-combustion engine, with particular application to the small stationary engine for farm use. Part two deals with the construction as well as the operation of the various types of farm tractors. The text is both clear and practical and the various topics are treated in detail.

FOREMANSHIP AND SUPERVISION. By F. Cushman. Second edition. John Wiley & Sons, New York, 1938. Cloth, 5 × 8 in., 286 pp., illus., diagrams, charts, tables, $2.50. A practical handbook for foremen conference leaders, and supervisors of vocational education. It deals with the conference type of educational procedure, which is distinguished by the stimulation of a group to active thought through the efforts of a leader who encourages and guides discussion, as opposed to other types of procedure in which the leader acts as instructor.

FUNKTIONENTAFELN mit Formeln und Kurven. (Tables of Functions With Formulae and Curves.) By E. Jahnke and F. Emde. Third edition, revised. B. G. Teubner, Leipzig and Berlin, 1938. Cloth, 6 × 10 in., 305 pp., diagrams, charts, tables, 15 rm. In the new edition of this standard compilation of mathematical functions some seventy-five pages of the simpler functions have been omitted to make room for certain higher functions not previously included. As in previous editions, relief diagrams are used for graphic demonstration of certain functions, and the explanatory material is given in both German and English.

GREAT BRITAIN. Department of Scientific and Industrial Research. LUBRICATION RESEARCH Technical Paper No. 3. The FRICTION of an OSCILLATING BEARING, by A. Fogg and C. Jakeman. His Majesty's Stationery Office, London (obtainable from British Library of Information, New York), 1938. Paper, 6 × 10 in., 28 pp., illus., diagrams, charts, tables, $0.30. The purpose of this investigation was to determine the characteristics of the friction of a journal bearing subjected to oscillating motion under different conditions of load, temperature, and frequency of oscillation, and to examine the effect of different lubricants on the friction.

Handbook of Aeronautics, Vol. 3. DESIGN DATA AND FORMULAE—AIRCRAFT AND AIRSCREWS. Edited by The Royal Aeronautical Society and the Institution of Aeronautical Engineers. Sir Isaac Pitman & Sons, London, Pitman Publishing Corporation, New York, 1938. Cloth, 6 × 9 in., 250 pp., diagrams, charts, tables, $6. This third volume is devoted to design data and formulas for aircraft and airscrews. Part 1, concerning aircraft, covers general conditions for ascertaining the strength of aircraft, and information concerning structural problems of all sorts. Part 2 covers theory, design, and effects of varying conditions of airscrews. Part 3 contains useful general tables, and a number of charts for graphic treatment of problems are collected in a pocket. The book is sponsored by The Royal Aeronautical Society.

HANDBOOK OF PETROLEUM ACCOUNTING. By R. W. McKee. Harper & Brothers, New York and London, 1938. Cloth, 6 × 10 in., 496 pp., diagrams, charts, tables, $5. This textbook furnishes a comprehensive discussion of the various accounting functions and procedures, and of accounting operations in the divisions of production, transportation, refining, marketing, etc. It is addressed to accountants, but should also be of interest to executives. Numerous practical forms are illustrated.

DER INDIKATOR. By K. J. DeJuhasz and J. Geiger. J. Springer, Berlin, 1938. Cloth, 6 × 10 in., 293 pp., illus., diagrams, charts, tables, 28.80 rm. The construction, operation, and use of the various types of mechanical, optical, and electrical-indicating instruments are described in detail. There is also discussion of the testing and gaging of indicators, of indicator dynamics, and of defective diagrams, as well as a brief history of the development of the indicator. There is a large bibliography.

MARCONI, the Man and His Wireless. By O. E. Dunlap, Jr. Revised edition. Macmillan Co., New York, 1938. Cloth, 6 × 9 in., 362 pp., illus., $3.50. The life of Marconi is portrayed against the background of his invention, wireless telegraphy. The resulting biography constitutes a history of radio as well. Many historic events are related, together with the ordinary occurrences of a man's life and the developments of a new scientific field. This revised edition contains an account of his death.

METAL AIRPLANE STRUCTURES. By F. E. Loudy. Norman W. Henley Publishing Co., New York, 1938. Cloth, 6 × 9 in., 455 pp., illus., diagrams, charts, tables, $5. A practical treatise on the design and construction of the major component parts of metal airplanes. Discusses the various types, materials of construction, structural elements, welded and riveted joints, stressed skin design, metal wings and beams, fuselage, and hull and float design. Contains tables, diagrams, formulas, and numerous illustrations.

METALLURGY. By C. G. Johnson, R. S. Dean, and J. L. Gregg. American Technical Society, Chicago, 1938. Cloth, 6 × 9 in., 149 pp., illus., diagrams, charts, tables, $1.50. A very concise elementary textbook in which physical metallurgy is emphasized.

MITTEILUNGEN AUS DEN FORSCHUNGSANSTALTEN DES GHH-KONZERNS. Bd. 6, Heft 6, July, 1938, pp. 143–168. V.D.I. Verlag, Berlin. Paper, 8 × 12 in., illus., diagrams, charts, tables, 2.90 rm. The first paper, on "Some Problems of Heat Transfer," discusses the graphic determination of the average temperature of the laminar boundary layer. The second describes recent improvements in electric motorcars for rack railways. The third paper discusses the hydraulic properties of blast-furnace slags.

MITTEILUNGEN AUS DEN FORSCHUNGSANSTALTEN DES GHH-KONZERNS. Bd. 6, Heft 7, August, 1938, pp., 169–194. V.D.I. Verlag, Berlin. Paper, 8 × 12 in., illus., diagrams, charts, tables, 2.90 rm. Of the two articles in this publication, the first is a continuation from the July number of an article on the "Hydraulic Properties of Blast-Furnace Slags" as used in cements, parts 7, 8, and 9 herein covering strength, swelling or shrinking, evolution of heat in setting, and the practical conclusions. The second article describes the effectiveness of a centrifugally controlled vibrator in eliminating excessive resonance effects in freely vibrating screening machines.

PHYSIK DER MECHANISCHEN WERKSTOFFPRÜFUNG. By W. Späth. J. Springer, Berlin, 1938. Cloth, 6 × 10 in., 179 pp., illus., diagrams, charts, tables, 14.60 rm. Dr. Späth has undertaken a critical examination of the basic physical questions in the testing of materials, with the aim of finding a secure basis for the immense number of observations that are constantly being made, and of establishing the connections between static and dynamic testing.

PRACTICAL SHELL DEVELOPING for Steel Shipbuilders. By A. F. Tulin. Crosby Lockwood & Son, London; Simmons-Boardman Publishing Corporation, New York, 1938. Cloth, 6 × 9 in., 153 pp., illus., diagrams, charts, tables, $3. A manual for loftsmen, shipfitters, hull draftsmen, and others who deal with steel ship construction. The work explains the development and laying out of the shell of a vessel, considering mainly the points of mold-loft procedure beyond the minor fundamentals which are assumed as familiar.

PRINCIPLES OF MOTOR FUEL PREPARATION AND APPLICATION, Vol. 1. By A. W. Nash and D. A. Howes. Second edition. John Wiley & Sons, New York, 1938. Cloth, 6 × 10 in., 628 pp., illus., diagrams, charts, tables, $9.50. This comprehensive work comprises two volumes, of which volume 1 is here considered. It deals fully with the production of motor fuels by distillation, cracking, extraction from natural gas, and hydrogenation. It also contains chapters on the production of benzole and various synthetic fuels, including alcohols, on general storage and distribution, and (in this second edition) pyrolysis and polymerization processes. There is a patent index.

A.S.M.E. NEWS

And Notes on Other Engineering Activities

High Speed, High Pressure, High Temperature, Themes of A.S.M.E. 1938 Annual Meeting in New York City, December 5–9

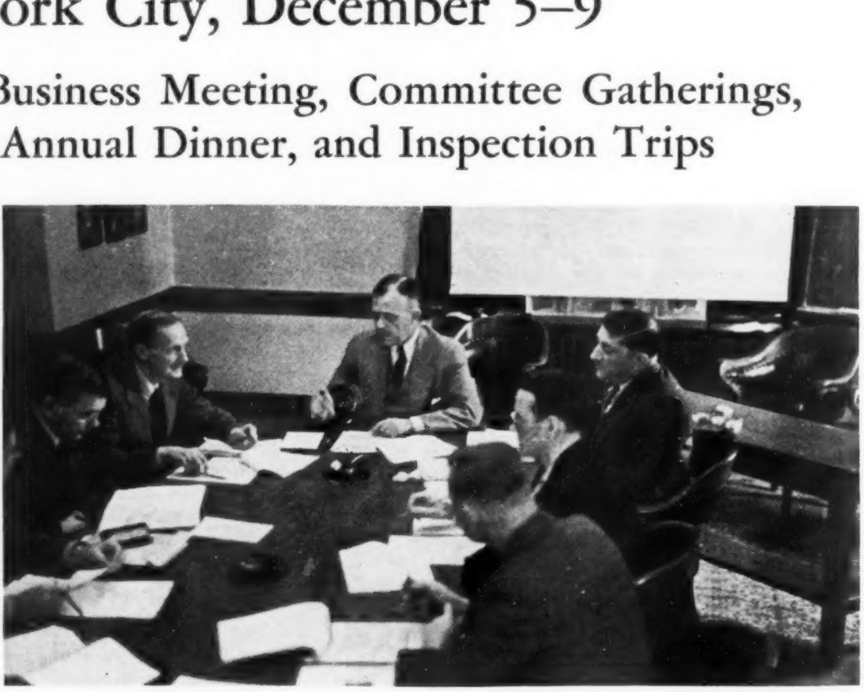
Technical Sessions, Business Meeting, Committee Gatherings, Honors Night, Annual Dinner, and Inspection Trips

PRESENTING the latest developments in the fields of machine tools, steam power, aeronautics, management, metals, fuels, instruments, textiles, hydraulics, lubrication, railroads, and ordnance, the Fifty-Ninth Annual Meeting of The American Society of Mechanical Engineers will be held at the Engineering Societies Building in New York City, Dec. 5–9, 1938.

Engineers from all parts of the world will be there to present the results of their studies and researches in all phases of mechanical engineering with particular emphasis on high speed, high pressure, and high temperature. For each engineer who speaks, there will be present twenty five others who came to listen and to learn in order to keep up with this fast-moving world.

Administration of Society Affairs

During that one week in December, delegates from the 71 Local Sections of the Society will meet to discuss ways and means of increasing the usefulness of the organization to the individual member. Then for the first time in many a year, a conference of delegates of the 17 Professional Divisions will be held for the purpose of correlating Division activities better to promote the art and science of mechanical engineering as a whole.



MEETINGS AND PROGRAM COMMITTEE DISCUSSING 1938 ANNUAL MEETING PLANS
(Sitting around table, left to right, R. F. Gagg, Erik Oberg, A. L. Kimball, Clarke Freeman, chairman, Ernest Hartford, secretary, W. W. Lawrence, junior adviser, and W. J. Wohlenberg.)

The Council, governing body of the Society, will assemble, not once but several times during that week, to transact the many items of business which occur in the conduct of a national engineering organization of 15,000 engineers. Many fine details of business will be worked out that week at the sessions of the various standing and technical committees of the Society. All members will review the doings of Council and the committees at the Business Meeting which is scheduled for Monday afternoon, Dec. 5.

Many Social Events

Luncheons and dinners have been planned by several groups, including the Management Division, the Junior Group, student members, etc. But the big social events are, as always, Honors Night on Tuesday, December 6, when several will be honored with awards and medals by their fellow engineers, and the Annual Dinner on Wednesday, December 7, when the old timers will greet the newcomers and joviality and good fellowship will prevail.

As usual, there will be special events for the women. A well-organized and efficient Woman's Auxiliary in New York is providing an entertaining program.

Inspection Trips

There are so many points of interest in New York and its vicinity, that the committee in charge of inspection trips, at last reports, was confronted with the task of picking out from hundreds of possible trips, the ones which would appeal to most members. Consequently, it will be necessary to wait until next month to find out about the plant visits.

A.S.M.E. Calendar

of Coming Meetings

December 5–9, 1938
Annual Meeting
New York, N. Y.

February 23–25, 1939
Spring Meeting
New Orleans, La.

July 10–14, 1939
Semi-Annual Meeting
San Francisco, Calif.

Tentative Program for 1938 Annual Meeting

MONDAY, DECEMBER 5

9:30 a.m.

Council Meeting
Sections Delegates' Meeting
Professional Divisions Delegates' Meeting

12:30 p.m.

Council and Sections Delegates' Luncheon

4:00 p.m.

Business Meeting

6:30 p.m.

Junior Members' Dinner
Time and Motion-Study Dinner—Management Division jointly with Personnel Research Federation

8:00 p.m.

Machine Shop Practice

Modern Hydraulic Units for Machine Tools, by K. R. Herman[1]
The Application of Hydraulics to Machine Tools, by Paul Jackson

Thermodynamics

Reheat Factors for Superheated and Wet-Steam Expansion, by Chas. G. Thatcher[2]
The Calculation of Steam-Turbine Reheat Factors, by Ronald B. Smith[2]
Friction Coefficients for the Compressible Flow of Steam, by Joseph H. Keenan[2]
New Measurement of the Specific and Latent Heats of Water and the Mechanical Equivalent of Heat, by N. S. Osborn, H. F. Stimson, and D. C. Grinnings

Aeronautics

Development of the Focke Helicopter, by Henrich Focke
Progress Report on Aeronautics

TUESDAY, DECEMBER 6

9:30 a.m.

Pipe Stress Problems

The Determination of the Expansion Forces in Piping by Model Tests, by H. W. Semar[2]
Progress Report on Creep Tests of Tubular Members
Progress Report on Relaxation Tests

Job Evaluation

Job Evaluation, by J. E. Walters
A Specific Application of Job Evaluation, by A. W. Bass, Jr.

Graphic Arts

Roll Curve Gears, by H. E. Golber[2]
Engineering and the Graphic Arts, by T. E. Dalton

[1] Published in this issue.
[2] Preprinted for Meeting; to be published later.

Iron and Steel

Hard Surfacing Processes and Materials, by M. L. Begeman[2]
Some Observations on Yield Point of Low-Carbon Steel, by Joseph Winlock and R. W. E. Leiter

12:30 p.m.

Maintenance Luncheon of the Management Division

2:00 p.m.

Power-Fuels

Modern Boiler Furnaces, by E. G. Bailey[2]
Report of Boiler Feedwater Studies Committee, by C. H. Fellows

Machine Shop Practice

Effects of Size and Shape of Cut Upon the Performance of Cutting Fluids When Turning SAE 3140 Steel, by O. W. Boston, W. W. Gilbert, and L. V. Colwell[2]
Electric Pressure Gage, by S. B. Terry and C. M. Hathaway

Industrial Instruments

Quantitative Analysis of Single-Capacity Processes by A. F. Spitzglass
Operating Experiences and Graphical Analysis of Automatic Combustion Control, by P. W. Keppler

Elasticity—Applied Problems and Mechanical Springs (I)

Stresses in Helical Compression Springs, Present Status of the Problem, by C. T. Edgerton
Analysis of Effect of Wire Curvature on Allowable Stresses in Helical Springs, by A. M. Wahl[2]
A Method of Calculating Energy Losses During Impact, by C. Zaener and H. Feshbach

Organization

Untangling the Corporate Harness, by Marvin Bower[3]
Organization Designed for Modern Business Conditions, by F. E. Raymond

8:00 p.m.

Honors Night

WEDNESDAY, DECEMBER 7

9:30 a.m.

Oil and Gas Power

Five Years Progress of Oil and Gas-Power by H. E. Degler
The Vectorscope—a New Instrument Useful in the Solution of Problems Pertinent to Study and Design of Internal-Combustion Engines, by G. J. Dashefsky

[2] Preprinted for Meeting; to be published later.
[3] Scheduled for December MECHANICAL ENGINEERING.

Metal-Forming Processes

The Effect of the Speed of Stretching and the Rate of Loading Upon the Yielding of Mild Steel, by E. A. Davis[2]
Tension Devices in Rolling Strip, by Morris Stone
The Forces Required for Rolling Strip Under Tension, by A. Nádai

Mechanical Separation

Problems and Trends in Centrifugal Machine Application, by J. S. Pecker[2]
Filtration Trends, by E. E. Flynn

Textiles

Superdraft Roving, by Carl Brandt
Twenty Years of Machinery Activity in the Woolen and Worsted Industry, by A. W. Benoit[2]

12:30 p.m.

Textile Luncheon
Job Shop Luncheon
Student Luncheon

2:00 p.m.

Hydraulics

Investigation of Error in Pitot Tubes, by Clyde W. Hubbard[2]
Pitot Tubes in Large Pipes, by E. S. Cole and E. Shaw Cole[2]

Elasticity—Applied Problems and Mechanical Springs (II)

Deflection of Helical Springs Under Transverse Loadings, by W. E. Burdick, F. S. Chaplin, and W. L. Sheppard[2]
Strength of Metals, With Special Reference to Spring Materials, by D. J. McAdam, Jr., and R. W. Clyne
Research Report on Helical Springs, by C. T. Edgerton

Lubrication

Thin Oil Films, by Walter Claypoole[2]
Wear in Lubrication Problems, by L. M. Tichvinsky[2]

Power-Fuels

The High-Pressure High-Temperature Turbine-Electric Steamship *J. W. VanDyke*, by L. M. Goldsmith[2]
Industrial Power Plants, by C. W. E. Clark[2]

6:30 p.m.

Annual Banquet and President's Reception, Hotel Astor

THURSDAY, DECEMBER 8

9:30 a.m.

Safety

Control of Dust Explosions in Industrial Plants, by Hylton R. Brown[2]
Factory Layout and Safety, by F. J. Van Poppelen

(*Program continued on page 880*)

[2] Preprinted for Meeting; to be published later.

Program for 1938 Annual Meeting

(Continued from page 879)

9:30 a.m.

Fuels

Possibilities for Utilization of Pulverized-Coal Ash, by A. W. Thorson and John S. Nelles[1]

Progress Report on Fuel-Bed Tests at Hell Gate Generating Station, 1937–1938, by M. A. Mayers, W. H. Dargan, Jos. Gershberg, M. J. Williams, E. R. Kaiser, and B. C. Dalway

Railroad

Counterbalancing of Reciprocating Weights in Steam Locomotives, by A. I. Lipetz[2]

Electric Locomotives, by B. S. Cain[1]

Fluid Meters

Influence of Steam-Flow Metering Equipment on Piping Design, by R. M. Van Duzer, Jr.[1]

Effect of High Temperatures and Pressures on Cast-Steel Venturi Tubes, by W. S. Pardoe[2]

Coefficients of Orifices and Nozzles With Free and Also Submerged Discharge, by R. G. Folsom[2]

Effect of Pulsations on Orifice Meters, by S. R. Beitler[2]

Review of Flow-Nozzle Research With Oil, by E. E. Ambrosius

Pulsating Air Velocity Measurement, by Neil P. Bailey[2]

2:00 p.m.

Education and Training

The Cost of Apprenticeship, by Warner Seely

Industrial Training in the Air-Conditioning Industry, by Ray D. Smith

High-Temperature Problems

High-Temperature-Steam Experience at Detroit, by R. M. VanDuzer, Jr., and Arthur McCutchan[2]

Changes in a High-Pressure Drum to Eliminate Recurrence of Cracks Due to Corrosion Fatigue, by A. E. White[2]

Railroad

Motive-Power Characteristics and Lightweight Equipment, by R. Eksergian[2]

Annual Report of Progress in Railway Mechanical Engineering, by E. G. Young[3]

Applied Mechanics and Ordnance

Ordnance and Vibration Problems, by G. F. Jenks[2]

The Use of the Piezoelectric Gage in the Measurement of Powder Pressures, by R. H. Kent and A. H. Hodge[2]

Methods of Rotor Unbalance Determination, by J. G. Baker

Critical-Speed Behavior of Unsymmetrical Shafts, by H. D. Taylor

6:30 p.m.

Railroad Dinner — College Reunions

[1] Published in this issue.

[2] Preprinted for Meeting; to be published later.

[3] Scheduled for December MECHANICAL ENGINEERING.

Providence Holds 1938 A.S.M.E. National Fall Meeting in Spite of Hurricane and Flood

IN SPITE of tragedy and destruction brought to Providence by wind and water on September 21, the 1938 National Fall Meeting of The American Society of Mechanical Engineers was held in that rapidly recovering city on October 5 to 7, with headquarters at the Providence-Biltmore Hotel. Persons traveling to Providence by road and rail witnessed evidences of the shocking destruction of property, forest, and shore line that the southern portion of New England suffered as a result of the extraordinary hurricane. With thousands of trees blown down, buildings demolished or injured, and bridges and tracks obstructed, damaged, or completely washed out, it was gratifying to note how quickly the work of clearing away the wreckage had been undertaken and reconstruction begun. It was hard for visitors to believe that the ground floor of the hotel had been completely under water. Essential services in the hotel had been restored to such a point that no inconvenience was suffered by the guests.

Perhaps the most serious aftereffect of the hurricane, in so far as the meeting itself was concerned, was the reduction in attendance at the meeting. Out-of-town attendance was reasonably normal, but with the work of reconstruction in Providence and vicinity at full height, and with many members striving to make up for lost time resulting from interruptions caused by the disaster, local registration was less than it otherwise would have been. As it was, the attendance reached a total of nearly 400.

Many A.S.M.E. professional divisions sponsored sessions at Providence. The program of the meeting has appeared in previous issues and will not be repeated here.

Subjects Discussed at Fuels Sessions

Wednesday morning witnessed the start of the technical events with three simultaneous sessions devoted to fuels, machine-shop practice, and rubber. At the fuels session, George A. Orrok, Jr., junior A.S.M.E., read a paper on the new L Street Station of the Boston Edison Company, and Ollison Craig, member A.S.M.E., reported on some studies he had made of discharge temperatures from coal pulverizers. The second fuels session was held on Wednesday evening with papers by Ralph D. Booth (presented by his associate, C. H. Danforth) on trends in the design of fuel-burning equipment in recent applications on the eastern seaboard, and another by E. B. Glendenning, L. H. Ventres, W. A. Sullivan, and A. R. Black on the atomization of oil by small pressure-atomizing nozzles.

Three Machine-Shop Sessions

Six papers were sponsored by the Machine Shop Practice Division at its three sessions. At the first session Paul V. Miller, member A.S.M.E., reported on recent developments in thread-grinding practice, and Herbert S. Indge discussed the refinement of ground surfaces. Precision finishing of surfaces, as illustrated by the accuracy of borizing, was dealt with by Carl T. Guething at the second machine-shop-practice session, and W. P. Schmitter talked on gear design as influenced by modern loading practices.

The third shop session included a paper by W. E. Johnson, member A.S.M.E., entitled, "How Useful Is Your Sense of Proportion?" and another by B. P. Graves, member A.S.M.E. on motor drives and electric controls on machine tools.

Rubber Provides Four Papers

Under the auspices of the Committee on Rubber and Plastics, of the A.S.M.E. Process Industries Division, two sessions were held and four papers were presented. The history of rubber as an engineering material was presented by William C. Geer, and Ernest R. Bridgwater discussed synthetic substances with rubber-like properties at the first session on Wednesday morning. In the afternoon E. G. Kimmich spoke on production processes and problems in the rubber industry and F. L. Haushalter on the mechanical characteristics of rubber.

Jewelry Symposium Evokes Interest

A symposium on management problems in the medium- and low-priced jewelry-manufacturing industry was one of the three technical events scheduled for Wednesday evening. Five speakers contributed to the program. Edward O. Otis, Jr., presented an excellent survey of the origin and growth of the industry to date. Special aspects of the general subject matter covered by Mr. Otis were further explained by William L. Marchant, whose topic was "The Search for Consumer Preference;" Harold E. Sweet, who described distribution methods in the industry; C. M. Dunbar, who told about the manufacture of rolled-gold plate; and Archibald Silverman, whose subject, "The Problems of Syndicate Store Production," provided him an opportunity to tell a host of amusing and revealing stories.

Displays of the jewelry manufactured by the industry, and a machine, in operation, which made chain mesh, added to the general interest aroused by the excellent picture of the important jewelry industry of the Providence district presented by the five speakers.

Industrial-Instruments Session

"Design and Application of an Asymptotic Reset Controller to Sewerage Settling Business," was the title of the paper by R. P. Lowe read on Thursday evening at the session on industrial instruments sponsored by the Commit-

tee on Industrial Instruments and Apparatus of the Process Industries Division.

Condensers and Evaporators

A. J. German, member A.S.M.E., presented the first of the five papers delivered at the two power sessions. His subject was "Condenser-Tube Life as Affected by Design and Mechanical Features of Operation." At the same session a paper by James H. Harlow, member A.S.M.E., and R. A. Bowman, Junior A.S.M.E., reported tests on condenser performance with reduced cooling surface. The third paper, by H. K. Nason and J. D. Fleming, dealt with the control of slime and algae in industrial cooling waters. At the second session on power, held Friday morning, two papers on evaporators were read: "Industrial-Evaporator Design, Application, and Operation," by W. K. Adkins, and "Industrial Application of Evaporators in No. 1 Powerhouse of the Ford Motor Company," by W. W. Dulmage.

Textile Subjects Arouse Interest

Because of the importance of Providence as a textile center, the Textile Division sponsored two sessions and a public luncheon. George F. Bliss described the worsted system of spinning, including the spinning of rayon fibers, at the Thursday morning session, and was followed at the afternoon session by Albert Palmer, member A.S.M.E., with a paper entitled "Loom Picking Mechanisms," and Ralph L. Marble, whose subject was "The Development of the Shearing of Textile Fabrics." At the luncheon S. J. Kennedy spoke on the mechanization of spun-rayon fabrics.

Management and Powder Metallurgy

Friday morning provided simultaneous sessions devoted to management and powder metallurgy, in addition to one on power already noted. At the Management session, W. C. Zinck, member A.S.M.E., presented a description of the method used by his concern in the control of purchases, and Ray M. Hudson, member A.S.M.E. read a paper entitled "Industry, Labor, and the Public." Gregory J. Comstock's paper on powder metallurgy was enthusiastically received at the session sponsored by the Iron and Steel Division.

General Luncheon Well Attended

Members of the Society and their friends were privileged to hear Henry M. Wriston, distinguished president of Brown University, at the general luncheon on Wednesday noon. Harvey N. Davis, president of the Society, presided at the luncheon and introduced as the first speaker Col. F. Snowden Skinner, of the Rhode Island National Guard, who described some of the havoc wrought by the hurricane and the work of rehabilitation planned.

In an address of welcome, Honorable James E. Dunne, Mayor of Providence, paid warm tribute to the work of the engineers of the city; and the Attorney General for the State of Rhode Island, John T. Hartigan, speaking on behalf of the governor, His Excellency Robert E. Quinn, who had been called to Washington in connection with federal aid for the hurricane sufferers, spoke in terms of high praise of the effectiveness with which the public utilities

HENRY M. WRISTON

of the state had embarked on the work of rehabilitation.

Four members of the Society, all of whom were present at the luncheon, were honored for their fifty years of membership in the Society by being presented with the customary "Fifty-year" badges. They were Ralph E. Curtis, William A. Drewett, F. H. Schwarz, and Curtis H. Veeder.

Henry M. Wriston Defends the Machine

Dr. Wriston commenced his address by stating that all thinking depends on assumptions, and that if the assumptions are wrong the conclusions will be wrong. This he illustrated by reading a prediction, made by a Commissioner of Labor, 52 years ago, to the effect that "there may be room for further intensive, but not extensive, development of industry in the present area of civilization."

It was characteristic of the world, said Dr. Wriston, to think that the "Golden Age" was in the past; and with quotations from the third century A.D., the fourth century B.C., and the sixth chapter of Genesis he provided evidence to prove this point. The assumptions on which this type of thinking is based are false, and he asserted, "It is fairly good technique of reasoning to believe that if the same prophecy has been made again and again through all the ages and consistently has been wrong, it is wrong again."

That technical progress has run its course, he continued, is a false premise that is based on the observation of material things. It neglects the resourcefulness of the human mind, the energy of the human spirit, the stoutness of the human heart, and the power of imagination to enlighten the dark corners when once the mind and spirit of man peers into them.

"Everything we know of mankind," he said, "should give us confidence that men of the future will be as resourceful as we and our forefathers have been—and I hope infinitely more so," and he added that there was "therefore nothing madder or more foolish than the statement that there are too many scientists, and too many engineers, and too many inventors, and too much production." In his opinion, one thing was certain, that technical progress had not blocked economic advance. Poverty was not a modern invention, he said, for no poverty had been more grinding than that of people in the preindustrial-revolution era; no slums were more degrading than those of places where sweated industry had never come. There was no question, he contended, "that on the material side the mind and spirit and courage and faith and genius and skill of man have provided more than ever before for the common man." Disparity between rich and poor was not growing greater, he said, but less. "The common man now has slaves instead of being a slave—slaves of the lamp, of the car, and of the school." These changes, he pointed out, had not come from political moves to redistribute wealth, but from technical improvements and economic processes. "All these things convince me," he said, "that the assertion we have come to the end of technical progress and its benefits is wrong."

A second common belief, the falsity of which Dr. Wriston next proceeded to demonstrate, was that "the machine will devour us." Man has always been somewhat afraid of his own devices, he asserted, and "modern complexity" is a phrase much in the public ears. He showed that "the initial impact of power machinery was more severe than that of subsequent refinements," and, he continued, while there is admittedly greater complexity we have also "more experience, more power, more technique for dealing with it today." "Certainly," he continued, "the process of occupying and taming a continent, of building communications, of establishing simultaneously the industrial and agricultural revolutions was adequately complex," and he added, "Technical advance went hand in hand with the pioneer spirit, but it did not create the complexity." He gave examples of the successive waves of industrial development in this country and of the interdependence of men in the pioneer era, and stated that interdependence was not the result of engineering advance. "It would be difficult to argue," he said, "that the men of yesterday could better estimate the incidence of their actions upon others than the men of today," and offered the child-labor situation in the first impact of the industrial revolution as an example. Nor was politics ever simple. "The problems of politics are the same today as always—to induce men to use reason instead of passion, to select men of public spirit instead of political leeches for public office," he contended, and added, "The machine has not changed this—we have the radio, but it is not its existence but what is said over it that counts." This led him to the conclusion, "Engineering did not create our civilization and will not create a new civilization—neither will it destroy it."

"The distinguishing characteristic of man," said Dr. Wriston in closing his address, "is that he cannot only adapt himself to environment but environment to himself. So long as man has manliness—imagination, faith, courage, integrity—he will use material things to reshape his environment favorably. When dominated by fear, hatred, and other man-

destroying attributes, he will use material things to reshape his environment unfavorably. . . . The engineer gives us slaves—it is the will of man which dominates their use. If this be clear, it is the task of education and the church, of statesmen and businessmen, not to rail at the slaves, but to strengthen the will of man for their proper use."

Clambake Takes the Place of a Dinner

On Thursday evening upward of 150 members and guests were transported by bus and automobile to the Pomham Club, Riverside, R. I., for a clambake, and to listen to an address, "Industry Aids the Army," delivered by The Honorable Louis Johnson, Assistant Secretary of War. Presiding at the clambake was Frederick S. Blackall, Jr., chairman of the A.S.M.E. Providence Section.

Following a succession of courses in which clam juice, clam chowder, steamed clams, lobster, fish, and Indian pudding provided the staples, the diners settled back, a little stiffly, to enjoy the postprandial program. Mr. Blackall introduced President Davis, who spoke on engineering education, with particular reference to training men for the duties and responsibilities of management. Two of the Society's past-presidents, Charles T. Main, of Boston, and Ralph E. Flanders, of Springfield, Vt., were presented amid applause.

"Industry Aids the Army"

In introducing Secretary Johnson, Mr. Blackall recalled his long career of public service and his efforts to advance industrial mobilization in a program of cooperation of industry with the War Department. Following a description of ways in which "the army comes to the aid of our country," as demonstrated by contemporary events in the hurricane-stricken areas of New England, Secretary Johnson turned to the subject of his address, "Industry Aids the Army." He said in part:

"This subject is especially appropriate for discussion here in New England because the greatest contribution of industry toward military preparedness in the United States came from the New England mechanical genius, Eli Whitney, who introduced the principle of interchangeability of parts in connection with his development and manufacture of an American rifle. Applied originally to firearms, the idea soon won adherents throughout American industry and out of these beginnings were laid the foundations for mass production in the United States. More than any other single factor, our ability to produce goods of uniform quality in mass quantity has enabled our citizens to reap more than the normal share of worldly goods and to give to our manufacturers and to our laborers the advantages of the world's foreign markets.

"The idea of interchangeability of parts appealed especially to the military profession and in all of its arsenals and in its orders for munitions, both in peace and in war, it has uniformly and continuously insisted upon that feature. There were times during the World War when many of our manufacturers felt that the demands of the Army for interchangeability were too rigid and that the persistent requirements for the establishment of tolerances to within thousandths of an inch were too exacting. After the World War, however, industry reaped an abundant harvest in the lessons in interchangeability and tolerances that it had learned. More than any other factors, they paved the way for the tremendous development in manufacturing that featured American industrial expansion in the 1920's.

"Today, industry serves the Army in many ways. It cooperates and supports the War Department plan of national defense and works wholeheartedly especially toward the realization of its industrial mobilization program. Let me illustrate.

"To conduct a modern war successfully, a nation must have a program not only for the raising, organizing, and training of its manpower but also for their supply and equipment. For the latter purpose, the Army arsenals and depots are wholly inadequate. If we were to equip, for instance, all of the Army arsenals with the best of modern machinery and to staff them to their full capacity, they would be unable to produce more than ten per cent of the requirements of the Army in time of war. The function of the arsenals is rightly that of experimental laboratories rather than munitions factories.

"For the other ninety per cent of our munitions needs in an emergency, we must turn to civilian production. The Army definitely came to that conclusion shortly after the World War and as soon as industry learned that fact, its leaders volunteered to cooperate.

"To determine the capacity and the ability of American industry to produce the necessary munitions in time of war, the Army decided to make a complete survey of all of our principal plants and factories. Wherever our officials went, they met with industrial cooperation. Our officers inspected more than twenty thousand plants. Owners, managers, foremen, and engineers helped us at every step. Where information was meager or inadequate, many of the factories assigned their own officials, on their own time, and with their own money, to do the research work necessary to assist the Army in the survey of their establishments. One organization, to my knowledge, has just spent more than twenty-five thousand dollars in the last three months in conducting such a survey of its own and in preparing its own plant for possible use by the government in its industrial mobilization plan.

"In the discussions between the production engineers and the Army officers, questions involving industrial and business secrets often arose but information was never denied. Our representatives have appreciated the confidence placed in them by industry and I am proud to say the trust has never been violated.

"As a result of these surveys, we feel that with proper education industry can carry a major war load and take care of our civilian as well as our military needs in time of emergency. As a result of these studies, we have earmarked ten-thousand plants for war production. We have informed their managers and their proprietors as to the tasks to be imposed upon them in the event of war. All of them have expressed their ability to assume the task. All are eager to cooperate with the War Department in this important job. May I take this opportunity publicly to express the gratification of the War Department and my own for the splendid cooperative service that we have received from industry in the preparation of our industrial-mobilization program.

"Not only in our surveys but in the improvement of our designs of technical munitions and in the standardization of component parts for mass production, industry materially has aided the Army. Specifications and drawings of the War Department submitted to manufacturing plants have often been returned with constructive criticism and valuable suggestions appended.

"In the education of our own officers for procurement work in peace, and for planning industrial mobilization in war, industrial leaders have played an important rôle. To the Army Industrial College, where officers of the Army and Navy are trained for these assignments, have come many leaders of industry to lecture, to discuss mutual problems and to give the students the advantage of their experiences. They have spared neither time nor effort in helping the services to get a broader and more comprehensive view of the problems of industry.

"Never in the history of our country have industry and the Army better understood each other; and industry, I am frank to say, has come at least half way.

"One of the most potent agencies in the coordination of military and industrial effort toward our mobilization program has been the professional societies, among which I am happy to number The American Society of Mechanical Engineers.

"Your members, individually, as reserve officers, as civilian technicians, and as industrial executives, and your organization as a unit, have cooperated with the Army to the fullest extent. Your National Defense Division has freely given us its advice on many difficult technical matters, especially in reference to ordnance design. The War Department appreciates your many efforts. For my own part, I particularly value your mental attitude toward all engineering problems and I trust that more and more we of the Army will come around to your view on industrial engineering.

"There is a tendency manifest among military designers of arms, ammunition, and accessories to develop complicated machines not readily adaptable for mass production. Against such a trend, we must continually guard. We should strive to develop simple weapons, whose production would present little or no problems for industry. I realize that some degree of complexity in military weapons is inescapable but, frankly, I believe that there are too many complicated weapons in the Army.

"I am inclined to the general view that what private industry can make should be the deciding factor of what the Army can use and what private industry makes best is exactly what the Army must use.

"Power to produce should become the watchword of preparedness today, and production engineering, to which you engineers hold the key, should control that power. Our arsenals, our procurement districts, and, above

all, all of our military services should approach the problem with the eyes of a production engineer who knows and understands the engineering of design and comprehends equally well the capabilities and the practices of modern production methods. The more thoroughly these principles permeate the minds of our military men today, the better we shall be prepared to go to production on a large scale in time of emergency.

"In conclusion, may I say that not only industry, but labor, professional men as well as skilled artisans, and even unskilled workers, today are working to the ends of national defense. The whole nation is cooperating wholeheartedly with the War Department toward the realization of its industrial-mobilization program.

"Today, despite some serious shortages, we are better prepared than ever before in the history of our country, and in times such as these it is obvious that the need for preparedness is cogent. The world of realities indicates quite clearly that some of the members of the family of nations make force and the threat of force their national policies. So long as that situation exists, we must stand on guard. We must keep America well armed. We must be ready, but mark you, not for offense but for defense, not for aggression, but for protection, not to wage war, but to keep America out of war."

Many Rhode Island Plants Visited

Opportunity was provided on Thursday and Friday afternoon for visits to a number of world-famous plants located in the vicinity of Providence. At the Brown and Sharpe Manufacturing Company a number of inspection tours were provided so that persons interested in specific aspects of the company's work could concentrate their time on what interested them most. All groups ended their tours of inspection at an attractively arranged exhibition of the principal products of the company's manufacture.

The trip to the Providence plant of U. S. Rubber Products, Inc., worked in nicely with the emphasis given the subject of rubber in the four technical papers sponsored by the Committee on Rubber and Plastics.

At the Gorham Manufacturing Company visitors witnessed the interesting handicraft operations in the production of fine silverware. The Esmond Mills, where wool blankets of national reputation are manufactured, the textile phase of the Providence district was ably demonstrated. A variety of manufacturing processes were inspected at the Providence Base Works, of the General Electric Company, where bases of incandescent lamps are produced by the hundreds of millions annually. Of especial interest to members of the Process Industries Division was a visit to the Narragansett Brewery.

Women Well Entertained

Cordiality and hospitality marked the efforts of the Committee on Women's Events, under the chairmanship of Mrs. Clarke Freeman, to give the wives of Society members and their guests a good time during the Providence meeting. Although the hurricane had destroyed some of the points along the route of the sight-seeing tours, evidences of the damage itself were of interest. The women also participated in the luncheon and clambake and many were present at the Jewelry Symposium.

The Committees That Planned It All

A.S.M.E. meetings are conducted under the auspices of the Committee on Meetings and Program, Clarke Freeman, chairman, and the technical papers are under the supervision of the Committee on Professional Divisions, L. K. Sillcox, chairman. The Providence Committee was under the leadership of Frederick S. Blackall, Jr., general chairman, A. W. Calder, Jr., general secretary. The following committees of Providence members arranged for and conducted the special activities that are essential to the conduct of a national meeting: *Reception*, William H. Kenerson, chairman, assisted by John G. Aldrich, Samuel J. Berard, Carroll D. Billmyer, Benjamin G. Buttolph, John S. Chafee, James H. Connolly, Paul C. DeWolf, Ralph L. Fletcher, Frederick C. Freeman, Hovey T. Freeman, Harold F. Gibling, Chester Hacking, Herbert B. Lewis, Albert J. Loepsinger, Irving W. Lovell, Morell MacKenzie, Edmund C. Mayo, Elmer H. Neff, Randolph T. Ode, Charles G. Richardson, Harold S. Sizer, William A. Viall, and Royal L. Wales; *Information and Registration*, W. A. Kennedy, chairman, assisted by A. William Meyer and F. A. Sawyer; *Technical Events*, Z. R. Bliss, chairman, assisted by Samuel J. Berard, Grove S. Dow, and Roger M. Scott; *Plant Trips and Transportation*, John D. Eldert, chairman, assisted by Charles S. Barningham, Chester Hacking, Herbert B. Lewis, and Paul A. Merriam; *Entertainment*, N. D. MacLeod, chairman, assisted by Alton C. Chick and A. William Meyer; *Finance*, Chester T. Morey, chairman; *Printing and Signs*, Wendell S. Brown, chairman, assisted by Randolph T. Ode and Harold E. Martin; *Hotel*, Paul N. Kistler, chairman; *Publicity*, L. E. Wagner, chairman, assisted by Augustus W. Calder, Jr., Everett Freeman, and A. William Meyer; *Women's Events*, Mrs. Clarke Freeman, chairman, assisted by Mrs. F. S. Blackall, Jr., Mrs. Z. R. Bliss, Mrs. Alton C. Chick, Mrs. Sidney Clifford, Mrs. Hovey T. Freeman, Mrs. William H. Kenerson, Mrs. George Lucas, Mrs. Morell MacKenzie, Mrs. C. G. MacLeod, Mrs. Norman D. MacLeod, Mrs. Edmund C. Mayo, and Mrs. H. D. Sharp.

Third Annual A.S.M.E. Photographic Exhibit, Dec. 5–9, 1938

ANY MEMBER of the A.S.M.E. may submit one or more photographs for the Third Annual A.S.M.E. Photographic Exhibit, on or before Nov. 15. As in previous years, both technical and nontechnical subjects will be acceptable. All pictures sent in should be mounted on 16 × 20-in. light-colored cards. Further details will be found on page 788 of the October, 1938, issue of MECHANICAL ENGINEERING. (The 16 × 120-in. size given there was a typographical error.)

New Orleans Assoc. of Commerce

A LOVELY PATIO IN NEW ORLEANS

A.S.M.E. Spring Meeting at New Orleans

February 23–25, 1939

THE SPRING Meeting of the Society will be held February 23 to 25, 1939, during Mardi Gras Week in New Orleans, thus affording members an opportunity of enjoying a brief winter vacation during one of the gayest of festivals with a program of papers devoted to Southern industries.

A special train on an economical all-expense plan will arrive in New Orleans on Mardi Gras morning, February 21, after a visit to Mammoth Cave, Ky., and a day at Birmingham, Ala.

Start making your plans now to attend the A.S.M.E. Spring Meeting at New Orleans. Later issues will carry further details of what promises to be one of the most enjoyable meetings ever held by the A.S.M.E.

News of the Woman's Auxiliary to the A.S.M.E.

THE MAYTIME Luncheon of the Woman's Auxiliary to the A.S.M.E. was held on May 19 at the Coveleigh Club, the former Col. Wainwright's estate on Long Island Sound. The sunken gardens of the Club and the vista of the Sound were an ideal setting for a most enjoyable luncheon meeting. Meeting the members and their guests at the Bronx Park Botanical Gardens, Mrs. J. H. R. Arms and her committee drove them through the blossoming highways of Westchester past the Fenimore Cooper estate to visit the artistic gardens of Mr. Moorhead, former Ambassador to Sweden. After luncheon the party drove to the gardens of Governor Lehman.

On Saturday afternoon, June 14, Mrs.

George W. Farny, president of the Auxiliary, entertained the members and their husbands with a tea given on her beautiful estate, Craftsman Farms, near Morris Plains, N. J. A musical program was given by the orchestra and soloists of the Essex County Opera Company and also by the Fife and Drum Corps of Post 59 of Morris County of the American Legion. The spacious lawn and attractive gardens were a perfect stage for this concert and the gracious hospitality of the hostess made the afternoon unusually enjoyable.

On August 6 the Auxiliary lost through death one of the oldest and loyalest of its members, Mrs. W. S. Huson. Her happy personality will be much missed, and especially so at the Annual Meeting where she always took charge of the women's registration.

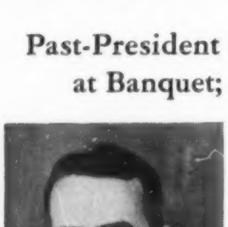
At Philadelphia at the Engineers' Club, on May 19, Mrs. G. L. Knight met a group of 16 women who organized the Philadelphia Section of the Auxiliary. The following officers were elected: Mrs. Coleman Sellers 3d, chairman; Mrs. C. C. Jones, recording secretary; Mrs. D. S. Walker, corresponding secretary; Mrs. J. S. Morehouse, treasurer; Mrs. E. L. Hopping and Mrs. L. P. Hynes, chairmen of Ways and Means; Mrs. J. P. Harbeson, chairman of membership; Mrs. H. E. Corl, chairman of hospitality; Mrs. K. M. Irwin, chairman of education.

The fall Luncheon of the Auxiliary will be held at the Engineering Woman's Club on Thursday October 13 at 12:30 p.m. when Miss Caroline Hood will speak on "Behind the Scenes of Rockefeller Center." Mrs. J. McQueeny will officiate as chairman of the hospitality committee, succeeding in that office Mrs. Gulbransen who has recently moved to Syracuse.

BURTIE HAAR.
Chairman, Publicity Committee

Papers on Economics, Machinery, Plywood at Wood Industries Meeting, Sept. 22–23

Past-President Herron and Governor Clyde R. Hoey Speak at Banquet; R. H. McCarthy Elected New Chairman



R. H. MCCARTHY

THE NATIONAL meeting of the Wood Industries Division of the A.S.M.E. was held this year on September 22 and 23 at High Point, N. C., directly following that of the Cost Division of the Southern Furniture Manufacturers' Association, so that members of both organizations were able to take advantage of both conventions. Headquarters were at the Sheraton Hotel.

Sessions were held on economics and waste, machinery, and glue plywood at which some fourteen papers were presented and discussed. At the economics and waste session on Thursday morning, Sept. 22, papers were presented on obsolescence in woodworking machinery, the engineer in cost accounting, manufacturing insulation material from forest waste, and reduction of waste and labor cost in rough dimensioning. In the afternoon visits were made to the Myrtle Desk Co., to the Marietta Paint & Color Co., and to the Tomlinson plant.

Past-President Herron Talks at Banquet

At the banquet in the evening James H. Herron, past-president of the A.S.M.E., gave an excellent talk on the history and development of woodworking hand tools which he illustrated with a fine selection of lantern slides. He was followed by the Hon. Clyde R. Hoey, Governor of North Carolina, who spoke on industrial development in that State.

Serving as toastmaster upon this occasion was Paul Bilhuber, a member of the executive committee of the Division and during the course of the evening he presented to the new chairman of the Division for 1939, R. H. McCarthy, a gavel whose barrel was made of English oak and handle of American oak. Mr. Bilhuber assured his audience that he knew the woods were authentic because on his vacation this last summer he had donned a diver's helmet and taken a little jaunt down 30 feet into Lake Champlain to obtain the wood from the *Royal Savage*, the flagship commanded by Benedict Arnold and sunk by the British at Valcour, N. Y., on October 11, 1776. He was roundly applauded for this feat.

Plywood Discussed

At the machinery session on Friday morning papers were presented on experiments in wood planing and on the elastic theory of wood failure, while the evening session was given over to the discussion of plywood, with papers on liquid resin as a plywood adhesive, exposure tests of water-resistant glue joints, and training men for the wood industries.

Friday afternoon was spent in visits to the plants of B. F. Huntley Furniture Company and to the Statesville Plywood & Veneer Company.

The meeting was voted a great success. It had everything that such a meeting should have—a city in which the furniture industry plays a large part, good technical sessions, lively discussion, worth-while inspection trips, and interesting speakers.

A.S.M.E. Awards for 1938 Announced

Will Be Presented at Annual Meeting

THE BOARD of Honors and Awards at its meeting of Sept. 26, 1938, announced that the following awards will be conferred at the 1938 Annual Meeting of The American Society of Mechanical Engineers:

The Holley Medal to Francis Hodgkinson, consulting engineer, New York, N. Y.

The A.S.M.E. Medal to Stephen J. Pigott, director in charge, John Brown & Company, Clydebank, Scotland.

The Worcester Reed Warner Medal to Lawford H. Fry, railway engineer, Edgewater Steel Co., Pittsburgh, Pa.

The Melville Medal to A. I. Lipetz, American Locomotive Company, Schenectady, N. Y., for his paper, "The Air Resistance of Railroad Equipment."

The Junior Award to Arthur C. Stern, junior member, New York, N. Y., for his paper, "Separation and Emission of Cinders and Fly Ash."

The Charles T. Main Award to Edward M. Connolly, University of Detroit, Detroit, Mich., for his paper, "Economic Limitations in Engineering Design—With Concrete Examples."

The Postgraduate Student Award to Marshall C. Long, Princeton University, Princeton, N. J., for his paper, "An Investigation Into the Angular Characteristics of an Adjustable-Blade Current Meter."

The Undergraduate Student Award to Donald C. McSorley, Michigan State College, E. Lansing, Mich., for his paper, "Humidity Insulation."

The Pi Tau Sigma Award (founded in 1938) to Wilfrid E. Johnson, General Electric Company, Fort Wayne, Ind., for "outstanding achievement in mechanical engineering."

Members of the Board of Honors and Awards are L. P. Alford, chairman, Harte Cooke, W. H. Carrier, J. W. Roe, R. V. Wright, and E. A. Horner, junior advisory member.

Nominations for the A.S.M.E. Medal, the Holley Medal, and the Warner Medal, were made to the Board by the Committee on Medals which consists of the five members of the Board of Honors and Awards and J. L. Harrington, D. C. Jackson, Robert Sibley, C. L. Bausch, F. M. Gunby, R. L. Sackett, E. R. Fish, H. C. Meyer, Jr., L. W. Wallace, H. A. Everett, H. A. S. Howarth, G. A. Orrok, Alexander Klemin, E. W. O'Brien, and E. S. Pearce.

The work of reading all the student papers and recommending to the Board the recipients for the Charles T. Main Award and the A.S.M.E. Student Awards was performed by the Committee on Relations With Colleges, consisting of W. A. Hanley, chairman, F. V. Larkin, H. O. Croft, E. W. O'Brien, A. C. Chick, and C. K. Holland, junior advisory member.

Dr. A. J. Büchi Receives Melville Medal at Special Meeting of Metropolitan Section

250 Hear Him Talk About Factors for Efficient and Economic Supercharging of Diesel Engines

AT A SPECIAL meeting of the Metropolitan Section under the sponsorship of the Oil and Gas Power Division presided over by Harte Cooke, vice-president A.S.M.E., Dr. Alfred J. Büchi of Switzerland, was presented with the 1937 Melville Medal by President Harvey N. Davis for his paper on superchargers which appeared in A.S.M.E. Transactions for February, 1937. To the applause of the 250 members who were present, Dr. Büchi accepted the gold medal and thanked the Society for the honor which had been accorded to him.

He then favored the meeting with an informal paper on "Deciding Factors for Efficient and Economic Supercharging of Diesel Engines." Illustrated with slides and blackboard diagrams, the talk, lasting more than an hour, traced the development of internal-combustion engine superchargers, described their use in marine and stationary installations, and, finally, enumerated their economic and operating advantages.

DR. BÜCHI RECEIVING MELVILLE MEDAL FROM PRESIDENT DAVIS

Other Local Sections News

Akron-Canton Hears About New 1939 Automobiles

Of common interest to all members of the Akron-Canton Section was the meeting on Sept. 22, in Akron when Robert Cass, chief consulting engineer, White Motor Company, revealed the latest designs and developments appearing in the new 1939 automobiles. The dinner preceding the meeting and the meeting itself were held in one of Akron's department stores, according to A. D. Maclachlan, the Section's able program arranger.

Cement Making Explained to Anthracite-Lehigh Members

With about 80 present in the Americus Hotel in Allentown, the Section heard Prof. William E. Reaser, member A.S.M.E., tell about combustion control in the cement industry. In recent years, said the speaker, instruments and automatic controls are replacing manual control in cement kilns. Charts were used to illustrate the economies which are made possible.

Diesel-Engine Lubrication at Central Illinois Meeting

Factors in the lubrication of high-speed Diesel engines were discussed by A. T. McDonald, research engineer, Caterpillar Tractor Company, in a paper presented before the Central Illinois Section in Peoria, Sept. 15. In it, Mr. McDonald showed how the satisfactory lubrication of an internal-combustion engine, once taken for granted as being accomplished when the crankcase was filled with oil, has developed into one of the most complex and involved problems of the engine designer. After tracing the developments in the field, he concluded with the statement that in spite of the amazing progress made in recent years in lubrication, this field of endeavor is still in its infancy. It is hoped that cooperative effort between engine designer and lubricant manufacturer will result in the perfect lubricant of tomorrow.

Charlotte Tobacco Meeting, Winston-Salem, Nov. 11

Meeting in Winston-Salem, N. C., on Tuesday evening, Nov. 11, the Charlotte Section will have as guest speaker, Horace L. Smith, Jr., president and chief engineer, Thermal Engineering Co., who is an expert in the treatment of tobacco in preparation for manufacture into the finished product. Risden P. Reece, member A.S.M.E., and chief engineer, R. J. Reynolds' Tobacco Co., is arranging the meeting.

Chicago Section Members Still Talking of Orr Night

Chicago Section members were still talking about the Sept. 23 smoker, arranged for Fred B. Orr, secretary-treasurer of the Section for 16 years and still going strong. Refreshments, entertainment, and the special program were arranged by T. S. McEwan and his crew of happy helpers. Henry M. Black, chairman of the Program Committee, says this was only the beginning; members will find much of interest in the many meetings which have been scheduled for the coming year.

Inspection Trip of the Cincinnati Section

Busses will leave Cincinnati on Oct. 27, one p.m., for an inspection trip through the Millers Ford Station in conjunction with the Akron-Canton Section. After dinner at the Akron Engineers Club, the two Sections will hold a joint evening meeting.

Cleveland Listens to Guns Over Europe

Cleveland Section members, wives, and sweethearts met on Oct. 3, at the Case Club to listen to a talk on "Guns Over Europe," by Prof. Jacob C. Meyer. It was a review of the social and economic conditions in Europe leading up to the present unrest.

Detroit Members Have Steel Trip and Meeting

Following an inspection in the afternoon of Oct. 18, of the new 1000-ton blast furnace at the Hanna Furnace Division, Great Lakes Steel Corporation, on Zug Island, members of Detroit Section held an evening meeting in the Book-Cadillac Hotel at which members of the American Welding Society and the American Society for Metals were the guests of the A.S.M.E. A. L. Foell, chief engineer, Arthur G. McKee & Co., spoke on "Modern Blast Furnaces."

Fire Fighting Discussed at Ithaca Meeting

Following dinner on Sept. 23, at the Madeleine Tea Room, members of Ithaca Section heard an interesting talk on and saw a demonstration of modern methods of fighting fires by C. B. White, chief chemist, American-La France and Foamite Corp. Mr. White did such a fine job, that F. S. Erdman, secretary of the Section, is trying to arrange to make the talk available to other Sections.

Mid-Continent Renders Valuable Service

During the latter part of August the Mid-Continent Section, A.S.M.E., performed a valuable service for manufacturers of pressure vessels in Tulsa who were unable to comply with a law passed in Texas requiring the placing of an A.S.M.E. stamp on their products because of the absence of an inspection service in Tulsa. When the matter was brought to the attention of Emory Kemler, chairman of the Section, and other officers, they arranged for an appointment by one of the insurance companies of a National Underwriters

licensed inspector, his salary to be borne by the companies benefited. After a trial period of several months, the manufacturers voted to continue the service which was originated through the efforts of the Section officers.

Since Sept. 12, the Mid-Continent Section has held several meetings, some being luncheons and dinners, others being joint meetings with the Tulsa Engineering Club. Total attendance has ranged from 63 to 127, of which at least one third were A.S.M.E. members.

Kansas City Has Dinner With Turbogenerator

Dinner with a 37,500-kva turbogenerator "at the table" was the enjoyable experience of members of the Kansas City Section at their Sept. 28 meeting. As guests of the Board of Public Utilities, Kansas City, Kan., nearly 100 members and guests had dinner on the turbine floor of the city's new power plant. Following an address by J. D. Donovan, manager of production and distribution, in which he described the plant and its operation, an inspection trip through the plant followed.

A.S.M.E. and A.I.E.E. Louisville Meeting

A joint meeting of the Local Sections of the A.S.M.E. and A.I.E.E. will be held Oct. 28, in the auditorium of the Speed Scientific School, University of Louisville. Dean F. L. Wilkinson, Jr., member A.S.M.E. is to be the principal speaker.

Plant Meeting of New Orleans Section

More than 150 members and guests attended a joint meeting with the Louisiana Engineering Society on Sept. 12, at the plant of the Higgins Industries, Inc., boat builders. K. P. Kammer, chairman of the Section, after completing the business part of the meeting, introduced A. J. Higgins, president of the host company, who gave an entertaining talk, illustrated with motion pictures, on the subject of "Boats, Their Design and Manufacture, and Power Plants for Same."

211 at Pittsburgh Hear About Topping

Meeting at the William Penn Hotel on Oct. 4, 211 members and guests of the Pittsburgh Section heard a paper by J. H. Strassburger in which he reviewed the design and operation of two 850-lb, 400,000-lb per hr boilers and the 800-lb, 800-deg, 10,000-kw turbogenerators installed at the Weirton Steel Co. plant at Weirton, W. Va., in June, 1936, as a "topping unit" to the existing 225-lb, 500-deg system. According to Mr. Strassburger, the new installation provided additional electric and steam requirements, retired the 25-year-old 160-lb boiler plant, and reduced the coal consumption approximately 500 tons per day.

Dinner Meeting at Raleigh

Frank B. Turner, secretary-treasurer of the Raleigh Section, reported a dinner meeting on Oct. 14, which had as guest speaker, E. H. Gurney, president of the A.S.H. & V.E.

In Search of Black Gold at Rock River Valley

Both R. C. Glazebrook, chairman, and W. C. von Fischer, secretary-treasurer, of the Rock River Valley Section, in reporting a meeting for Sept. 22, are overabundant in praise of the speaker, F. P. Grutzner, member A.S.M.E., and assistant chief engineer, Fairbanks, Morse & Co. In his excellent talk, Mr. Grutzner covered the latest developments in the oil industry, including the newest methods and trends in engineering and geological surveying.

Carrier Talks at Syracuse

W. H. Carrier, member A.S.M.E., talked before the Syracuse Section on Oct. 10 on "Developments in Refrigeration."

Western Massachusetts Visits Reservoir

On Sept. 20, members and guests of the Western Massachusetts Section made an inspection trip to the site of the new Quabbin Reservoir, which is now under construction. After making a tour of the main dam and through and around the basin, the whole party had dinner at the Highland Hotel. Guest speaker was Frank E. Winsor, chief engineer, Metropolitan District Water Supply Commission, which is building the new reservoir.

Worcester Hears Perrine on Waves, Words, and Wires

At a joint meeting of the Worcester Section and the Worcester Engineering Society on Oct. 13, J. O. Perrine presented his lecture-demonstration on "Waves, Words, and Wires." It was thoroughly enjoyed by all.

Junior Group Activities

Mid-Continent Starts Membership Drive

MID-CONTINENT SECTION covers the entire states of Oklahoma, Arkansas, and a part of Louisiana. Therefore, it is interesting to hear of the program outlined by the Junior Membership Committee, consisting of Jack Laudermilk, chairman, Clarence Glasgow, Paul Gassett, and Fred Stewart. Each member of the committee has selected one or two cities where he will act as chairman of a membership subcommittee of local Juniors. Each subcommittee will be responsible for securing not only new members but those who have dropped out during the past few years.

The Junior Program Committee is doing its part by scheduling a series of weekly meetings with outstanding engineers as speakers. The first meeting held on Oct. 4 had G. Raymond, member A.S.M.E., and chief engineer, Black Sivalls & Bryson, Inc., speak on "Design of Unfired Pressure Vessels."

Boston Completes Plans for Junior Speakers

The Junior Group of the Boston Section, under the leadership of F. Robert Hartin, chairman, is making many plans for Junior activities during the coming year. At least one Junior Discussion Group Meeting is planned for each month at which Junior members will be given the opportunity to talk on the technical aspects of their own work with a view of becoming proficient in public speaking and in the preparation of technical papers. It is also planned to have several plant visits to near-by concerns.

South Texas Elects New Officers

Meeting at Rice Institute on Sept. 23, the Junior Group of the South Texas Section elected officers for the coming year and then heard R. W. Johnson, traffic engineer, talk about a traffic survey carried on in Houston by the W.P.A. The new officers are John Doggett, chairman; D. J. Parmeson, vice-chairman; and G. F. Fermier, secretary-treasurer.

Mr. Johnson described several traffic charts of the city which showed location of accidents, of accident-driver accidents, and of accident-pedestrian residents. It was interesting to note that most of the accidents were caused by people living in one region. The lecture also dealt with traffic problems in various parts of the city. After the meeting, several members who were gathered at a near-by refreshment stand, by coincidence, saw a first-class race down South Main Street of two ambulances, three wreckers, and numerous ambulance chasers.

Dinner for Junior Members, Dec. 5

ARRANGEMENTS have been completed for a Junior Members' Dinner on Monday evening, December 5, during the A.S.M.E. Annual Meeting. It will be held at the Roger Smith Restaurant, 40 E. 41st St., New York City. Cost will not exceed $1.50 per person.

A.S.M.E. Officers for 1939 Elected by Members

AFTER checking the 3622 letter ballots received from members throughout the country and throwing out 237 defective ones, the Tellers of Election, Henry B. Fernald, Jr., C. Kenneth Holland, and Cornelius C. Kirby, reported that the following nominees were elected directors of The American Society of Mechanical Engineers for 1939:

Office	Nominee	Votes
President	Alexander G. Christie...	3371
Vice-Presidents	Henry H. Snelling......	3366
	Wm. Lyle Dudley......	3361
	Alfred Iddles...........	3367
	James W. Parker.......	3368
Managers	Clarke Freeman........	3368
	William H. Winterrowd	3372
	Willis R. Woolrich.....	3370

Biographical sketches and photographs of the elected nominees may be found on pages 649–652 of the August issue of Mechanical Engineering.

TELLERS OF 1938 COUNTING THE BALLOTS

(Sitting left to right: Cornelius C. Kirby, C. Kenneth Holland, and Henry B. Fernald, Jr., Junior members A.S.M.E. D. C. A. Bosworth, Comptroller of the A.S.M.E., is looking on.)

With the Student Branches

Texas Student Branch Starts Off New Term With Mechanical-Engineering Frolic

Officers Write Personal Letter to Each Student and Help to Orientate Freshmen

ACTIVITY with a capital A is the main feature of the 1938–1939 aims and objectives of the Texas Student Branch. To initiate this new program, all mechanical-engineering students were invited by the A.S.M.E. to its Fall Frolic on Friday evening, Sept. 23. This was done by giving to each returning student as he registered, a bid to the Frolic and a brief personal letter describing the A.S.M.E. activities, signed by the four officers of the Branch, Joe F. Hill, chairman; Rudolph Bodemuller, vice-chairman; Harold B. Crockett, secretary; and W. H. Marsh, treasurer. The letter listed the following Branch objectives:

1 To give the student some acquaintance with the practical side of mechanical engineering.

2 To furnish the student with the principal publications of the Society and to keep him in touch with engineering progress.

3 To develop the student's initiative and ability to speak in public, and to familiarize him with the parliamentary procedure and organization of learned scientific societies.

4 To enable the student to establish fraternal contact with his fellow students in engineering, and to meet practicing mechanical engineers.

5 To give the student an opportunity to attend the general meetings of the Society.

A.S.M.E. Frolic

The party, attended by 175 students, sweethearts, and faculty members, was held on the patio of the engineering building where there was dancing to inviting melodies. Perhaps for the first time in its history, the patio was the scene of ping-pong, badminton, and bingo games. Free access was had to a punch bowl which was kept filled throughout the evening. Following a period of group singing, a floor show was presented in the library, with Harold Crockett as the cheerful master-of-ceremonies. There were thrilling songs by the beautiful prima donna of the University's Light Opera Company, Miss Bonny Ruth Taylor, six exhibition dance numbers, and a violin solo by Frank Monte, sophomore M.E. More dancing and game playing followed.

First Meeting

As a result of the party, the first business meeting of the Branch three days later saw more than 50 students sign membership applications. Wisely, Chairman Hill immediately organized several committees in order to keep things moving. Members of the various committees are as follows: *Program*, C. W. Simpson, chairman, W. E. Payne, and J. T. Vance; *Publicity*, Bill Besserer, chairman, Frank Lary, and G. S. Ormsby; *Membership*, E. M. Johnson, chairman, G. W. Oge, Jack Scanlan, and Fort Wilson; and *Inspection Trips*, Frank Goerner, chairman, Forrest Skoog, James Malone, and C. D. Schmidt.

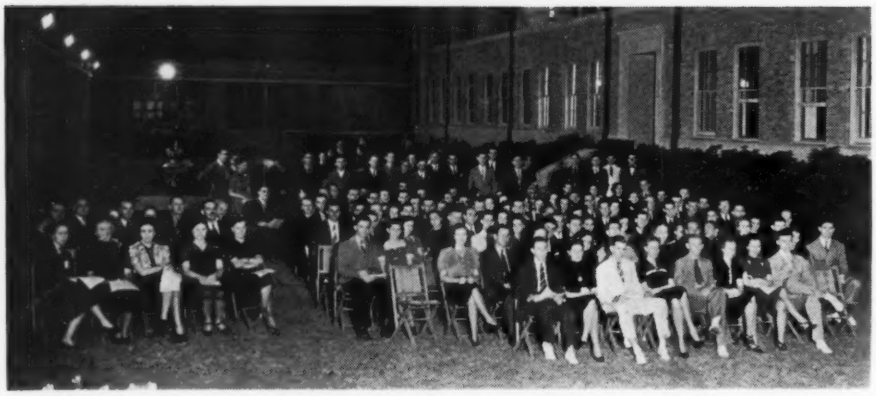
Freshmen Guide

Rudolph Bodemuller then read excerpts from a pamphlet prepared by Harold Crockett, Frank Goerner, James Malone, and himself, to help mechanical-engineering freshmen orientate themselves. Much to our regret, lack of space prevents the printing of the complete text, but following are a few interesting parts:

"Fellows, we upperclassmen wish to welcome you into our group, each man of which aspires to become a competent mechanical engineer. Few of us feel that we will ever become wealthy by following our chosen profession, although we probably did when we were freshmen. . . . As a group we have discovered that the joy of creation or of service rendered to mankind must be in a large measure recompense for our endeavors; that is, this is what we anticipate from observations o what others are doing. . . . If you do not get pleasure out of working hard, chiefly because you feel that you are doing a good job, perhaps you have chosen the wrong profession.

Once you have chosen the profession of mechanical engineering, you will find a wide variety of subjects from which to pick your specialized field. (Then followed a list of the professional divisions of the A.S.M.E.). . . . As you go through Texas University, remember that employers consider these qualities of an engineer (in order of importance): character, personality, judgment, ability to think problems through quickly using fundamental, initiative, ability to handle men, technical knowledge, and working technique."

After describing the department of mechani-



UNDER TWINKLING TEXAS STARS MECHANICAL ENGINEERING STUDENTS AND THEIR FRIENDS WERE GUESTS OF THE TEXAS UNIVERSITY STUDENT BRANCH ON SEPTEMBER 23 AT A PARTY HELD ON THE PATIO OF THE ENGINEERING BUILDING

Student Branch Secretaries

Please Note!

REPORTS of meetings and inspection trips must be received at Society Headquarters on or before the sixth of the month in order to appear in next month's issue of MECHANICAL ENGINEERING. Example: All copy received up to Nov. 7 will be in the December issue, etc.

PHOTOGRAPHS of student member groups are always welcome for use in MECHANICAL ENGINEERING. Prints should be preferably glossy and of good contrast. However, send in everything you have and the editorial department will use those it can reproduce.

PUBLICITY is always good for the branch. Clippings from school and local newspapers should be sent in with your reports.

cal engineering in the University and the TEXAS STUDENT BRANCH of the A.S.M.E., the guide propounds the blunt question, "Can you study?" To help the student answer this, the authors make several suggestions, among which are found the following:

"Do not work crossword puzzles in class, especially in the front row. Do not sketch or doodle during a lecture. If you feel it absolutely imperative to write assignments for another class, at least have the decency to apologize to your instructor. . . . Use the Engineering Library and the Pi Tau Sigma study table. Read technical magazines, for example, MECHANICAL ENGINEERING."

Following this is a list of organizations which offer different advantages to the student. Then about the joint effort of the engineering school which is the annual Power Show, the guide says:

"Every spring the College of Engineering polishes up its equipment and shows it to the public. The whole show is run by the students, although the faculty lend indispensable aid in planning many of the exhibits. That we are constantly in search of new ideas for making the affair more appealing to the public need not be said. You freshmen who join the A.S.M.E. will have an opportunity to participate in the show and thus will get a chance to get the feel of mechanical engineering. Even if you do not take part, do not fail to come, for there you will get your first working conception of the wonders of engineering. Visiting the show might lead you to feel that perhaps you are more attracted by some branch of engineering other than mechanical; if so, it is well that you should find this out early in your college career."

And Now, the Other Branches

More than 80 members attended the CALIFORNIA BRANCH initiation banquet on Sept. 15. As part of the entrance requirements, new members were required to submit drawings of "crazy inventions." C. R. Coffee won the prize with a design for a left-handed crescent wrench. The speaker of the evening was Mr. Olson, who talked on the "Seamier Sides of Engineering," which included many stories of his varied and interesting experiences in Canadian lumber camps.

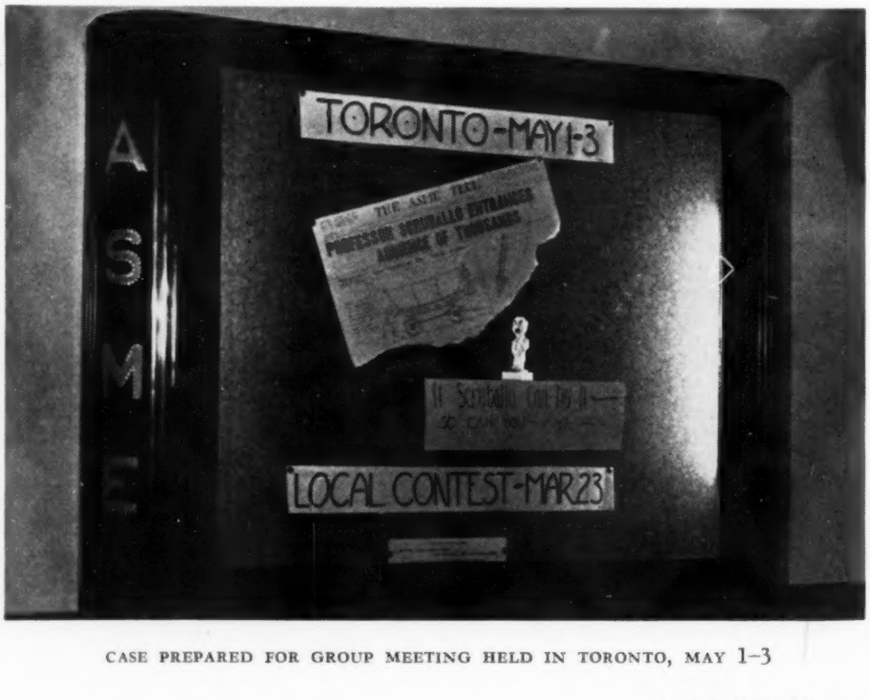
CLEMSON AGRICULTURAL COLLEGE BRANCH has an Admissions Committee which examines the scholastic records of all applicants for membership. At the Oct. 3 meeting, sixteen juniors and five seniors were declared eligible for membership.

C.C.N.Y. BRANCH, besides its program of technical meetings and inspection trips to chewing-gum, paper, tin-can, and soap factories, has also made plans to enter teams in the intramural football and basketball leagues and to have smokers, dances, and theater parties. As a start, an induction smoker was held on Oct. 6 in the House Plan Center.

130 Attend Illinois and Also Iowa State Affairs

At its first meeting of the new term on Sept. 28, ILLINOIS BRANCH had 80 members and 50 visitors. After a few words on the advantages of membership in the A.S.M.E., John R. Poyser, chairman, introduced the speaker of the evening, L. R. Yeager, staff engineer, Owens-Illinois Glass Company, who spoke on "Fiber Glass." An article on this subject was printed in the October issue of MECHANICAL ENGINEERING on page 774.

IOWA STATE BRANCH had 130 students and guests at its annual smoker held on Sept. 28 in the M.E. laboratories. After group singing led by Bill Scott and Bill Sweatt, the traditional peace pipe was lighted and passed around. The officers were introduced and an outline of the year's program given by Charles King, the chairman of the Program Com-



CASE PREPARED FOR GROUP MEETING HELD IN TORONTO, MAY 1–3

mittee. Then followed the introduction of each man present and the serving of refreshments.

Iowa Holds Speech Clinic

On October 5, six members of the Iowa Branch presented short papers with an electrical recording being made of each talk. These were then played back to the audience and used in criticism and instruction in good and bad points in public speaking. The clinic was conducted by Dr. Harry G. Barnes of the speech department, and the recording and reproduction of the talks was directed by Dr. Grant Fairbanks.

Kentucky Branch presented three motion-picture films at its meeting on Sept. 30, which was attended by 58 members and visitors.

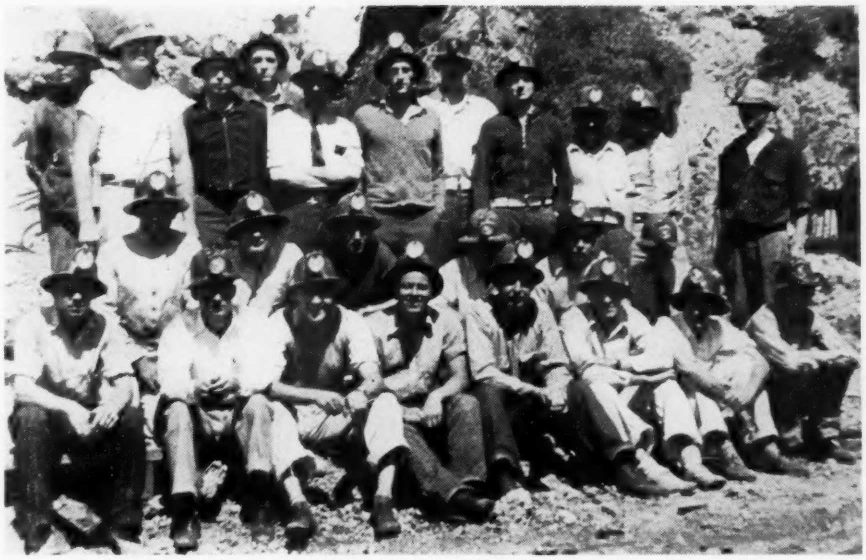
Louisville Branch at its meeting of Sept. 22, welcomed the new dean of the Speed Scientific School, Ford L. Wilkinson, Jr., member A.S.M.E.

Michigan Signs Up 41 New Members at First Meeting

Holding its first meeting on Oct. 5, in the Michigan Union, Michigan Branch had an audience of 40 members and 85 visitors. After the meeting, 60 students applied for membership, of which 41 were new applicants. For the first time in many years, Dean H. C. Anderson was not present to open the meeting, being prevented from attending by illness. However, Professors Erickson, Emswiler, and Vincent did a very able job of representing the faculty, especially Professor Erickson, who kept the program well tinted with amusement, jolly remarks, and interesting anecdotes.

Nebraska Branch held a dinner smoker on Sept. 21, which was open to all students of the mechanical-engineering department. After the dinner a film dealing with gas welding was shown through the courtesy of Linde Air Products Co.

Nevada Branch has discovered a way of getting the lowerclassmen interested in A.S.M.E. activities and building up the club treasury. It offers associate membership to freshmen and sophomores for dues of 50 cents a year. Juniors and seniors are required to pay the full $3.



ARIZONA STUDENT MEMBERS AND FACULTY AT THE MAGMA MINE IN SUPERIOR, ARIZ., APRIL 9, 1938

(Robert Parsons' description of the air-conditioning system of the mine won him first prize at the Southwest Unit Student Meeting.)

E. G. Hoefer Is Speaker at North Carolina State

E. G. Hoefer, chairman, Raleigh Section, A.S.M.E., was the guest speaker at the first meeting of the North Carolina State Branch on Sept. 28. Another high light of the evening's program was the presentation of a book to Sydney Rogers, for outstanding services to the branch during 1937–1938.

Northeastern Branch members spend ten weeks in school and a similar period in industry. Students are assigned either to A or B division, each division alternating with the other in school and in industry. Consequently, there are two groups of student members in the branch, A and B.

Pratt Branch had more than 100 members present at its first meeting on Oct. 6. Among the many things discussed were technical meetings and inspection trips for the coming year.

300 at Purdue Meeting

About 300 students were present at the first meeting of the Purdue Branch on Sept. 22. Prior to the start of the session, refreshments were served in an endeavor "to break the ice" for the newcomers. Chief speaker of the evening was Dean A. A. Potter, past-president A.S.M.E. 79 new members were signed up at the end of the meeting.

Vermont Branch members were guests of C. W. Price on a visit through the Ridder Manufacturing Co. plant in Burlington, Vt., on Sept. 30. Among the things seen were various kinds of machine tools and hand punches, which are the principal products of the company.

V.P.I. Doubles Membership

From signed applications filed at the first meeting of the V.P.I. Branch on Sept. 22, it is already apparent that the branch has more than doubled last year's membership, with a possibility that it might even be trebled if the attendance of 125 is any indication. Of course, some credit should go to Dean E. B. Norris and Prof. J. B. Jones, who gave such fine talks at this meeting on the many advantages of A.S.M.E. student membership.

Washington University Branch (St. Louis) is another group which features activity with a capital "A." At its first meeting on Sept. 27, the branch had as guest speaker none other than A. L. Heintze, chairman, St. Louis Section, A.S.M.E., who enumerated the many

WASHINGTON UNIVERSITY (ST. LOUIS) BRANCH ON AN INSPECTION TRIP THROUGH THE ST. LOUIS AIRPLANE DIVISION OF THE CURTISS-WRIGHT CORPORATION, SEPTEMBER 29, 1938

benefits enjoyed by A.S.M.E. members. Two days later, the members made an inspection trip to the plant of the St. Louis Airplane Division, Curtiss-Wright Corp., where the construction of new 30-passenger airplanes was observed.

WEST VIRGINIA BRANCH chairman, Kenneth E. Pyle, has been nominated for president of the General Engineering Society. So far, the election results haven't been received. Speaker at the Sept. 26, meeting was J. V. Balch, who presented a paper on the Salerni hydrokinetic power transmitter.

Transactions of World-Power and Large-Dams Meetings Soon Ready

APPLICATIONS are now being received by the American National Committee, Third Power Conference, Interior Building, Washington, D. C., for complete sets or individual volumes of the Transactions of the Third World Power Conference and the Second Congress on Large Dams which were held concurrently in Washington, Sept. 7–12, 1936. A booklet describing the contents of each set of Transactions together with order forms may be obtained by A.S.M.E. members directly from the Committee or from the U. S. Government Printing Office, Office of Superintendent of Documents, Washington, D. C. Prospective purchasers should send in their orders immediately to avoid the necessity and expense of two press runs.

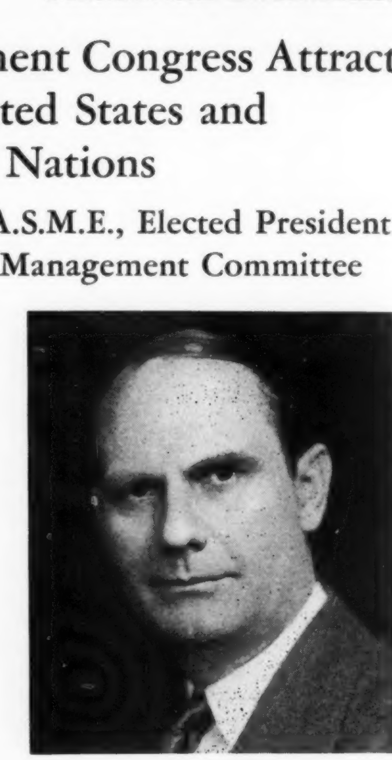
The Transactions will be published by the U. S. Government Printing Office, a circumstance which will permit their sale at a price much less than has heretofore been possible. While exact prices cannot be determined until after publication, estimates indicate that prices for the Conference Transactions will not exceed $22 per set of ten volumes, and $2.50 per single volume, and for the Congress Transactions will not exceed $10 per set of five volumes, and $2.50 per single volume.

Volume I of the Transactions of the Conference will contain a general chronicle of the meeting together with information on the "study tours" in which members participated. Other volumes cover the following subjects: II, Power resources, development and utilization; and significant trends; III, Statistics, collection, compilation, and publication; and organization of the production, processing, and distribution of coal and coal products; IV, Organization of the production, refining, and distribution of petroleum, petroleum products, and natural and manufactured gas; V, Organization and regulation of private electric and gas utilities; VI, Organization of publicly owned electric and gas utilities; and planning of conservation of natural resources; VII, Utilization of water resources, and regional integration of electric and of gas-utility facilities; VIII, Rationalization of distribution of electric energy and of gas, and rural electrification; IX, National power and resources policies; and general reports in English; and X, General reports in French, German, and Spanish.

International Management Congress Attracts 1500 From United States and 21 Other Nations

W. L. Batt, Past-President A.S.M.E., Elected President of International Scientific Management Committee

TRULY an international forum for the interchange of experiences in all phases of management was the Seventh International Management Congress held in Washington, D. C., Sept. 19–23, 1938. Sponsored by some twenty national technical, economic, statistical, and business organizations, of which The American Society of Mechanical Engineers was one, the Congress attracted about 1500 men and women from industry and management, not only from the United States and Canada, but from 20 other countries. Both technical and general sessions were well-attended, with participating audiences ranging from 100 to 500 individuals.



W. L. BATT, FIRST AMERICAN PRESIDENT OF THE INTERNATIONAL COMMITTEE ON SCIENTIFIC MANAGEMENT

W. L. Batt Elected President

William L. Batt, past-president A.S.M.E., and president, SKF Industries, was elected president of the International Committee on Scientific Management by a meeting of delegates from the seventeen member countries, Belgium, Brazil, Bulgaria, Czechoslovakia, France, Germany, Great Britain, Greece, Holland, Hungary, Italy, Poland, Rumania, Spain, Sweden, the United States, and Yugoslavia. The first American ever elected to that office, Mr. Batt will serve through until the eighth Congress, in Stockholm, Sweden, in 1941. An advocate of greater acceptance by business of its responsibilities to society, Mr. Batt served for more than a year as chairman of the American Coordinating Committee of the Congress just ended.

Management's Responsibilities

The program of the Congress was divided into two sections with over 200 papers presented in abstract by special rapporteurs, at six parallel technical sessions. This part of the program had in general the theme of improvement of techniques of management in administration, personnel, production, distribution, agriculture, and the home. The second part had as its theme the responsibilities of management as the functioning group in industry and trade which has the task of writing the objectives of labor and capital for the common good of both these factors and the public.

Management's responsibilities were clearly shown to have entered the professional field due to the advanced scientific methods of production. It was pointed out that to provide greater security, there must be a reorientation of business to the great economic and social forces which now surround and control their own activities. Management must be conducted along lines that will develop mutuality of interest of the executive and the workers, eliminating individual gain and unifying the forces of government, business, labor, and agriculture toward one common goal. This new concept of mutuality of interest must be foremost among the aims of enlightened industrial management.

General Management Session

The session on general management saw the expression of different points of view about the relation between government and industry. Dr. Seebauer presented the case for Germany in which he claimed that the situation of 1933, coupled with the limited geographical space and limited resources of his country had necessitated the imposition by central authority of the "community principle." Within the limits thus imposed, he said, industry is left free to organize itself and to develop. Then a Frenchman described the manner in which a certain French industry is attempting to rationalize itself. In this the employer, the consumer, and the public authority, each take a part. His general claim was that the public authority increasingly participates in such rationalization, but by general desire and consent rather than by compulsion. Lewis H. Brown pointed out, first, that no scheme of rationalization can hope to succeed unless strongly supported by "top management." He claimed, second, that in the United States there is developing the possibility of such collaboration between management and government agencies.

Personnel Sessions

In summarizing the thoughts brought out in the personnel sessions, Prof. Elton Mayo, Harvard University, chief rapporteur, stated

that the delegates were deeply concerned with the human social problems that lie beyond the industrial problems—problems that are indicated but not described by such phrases as "the social consequences of industrial development." This, according to Professor Mayo, was one of the most important achievements in that the speakers claimed science is not enough in the handling of human problems. This must not be taken as derogatory to the high office of science in all human advancement. To scientific method is owed all that is precise, all that is necessary in human knowledge. But in the handling of human affairs, it is necessary to return to a sphere of action where science, although it is perhaps the only source of aid, cannot in itself be entirely adequate. The abstractions a scientist is forced to make are rarely, if ever, coincident with the circumscription of a human problem.

The universities have served society admirably in the training of scientists; they have not yet devised effective methods for the training of the administrator. Training in those sciences that have contributed to the creation of a new industrial order is necessary but is not in itself enough. The student needs effective techniques of human and social investigation; he needs also the habit of human responsibility. This habit can only be acquired by the exercise of human responsibility under criticism and guidance. The world has great need of young men thus trained, and there is not much time.

Production Sessions

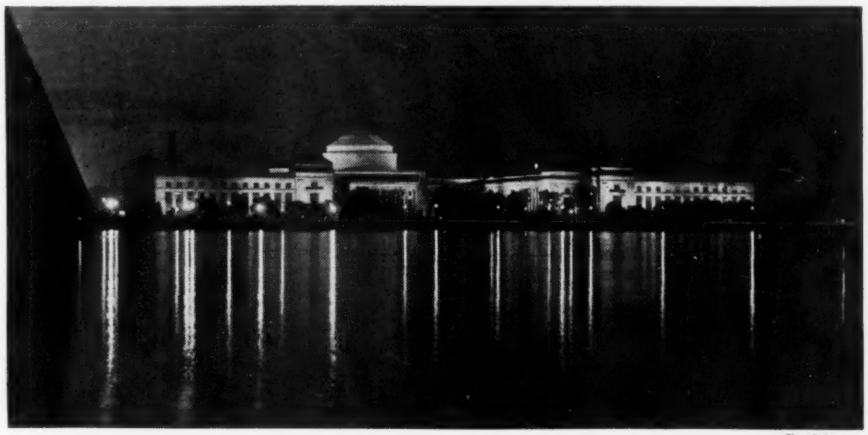
Six tendencies, according to Dr. Erwin H. Schell, M.I.T., are now generally approved by management. These tendencies, as brought out in the production sessions, are: Industrial research should more nearly approach scientific research by having results made available to all; serious fluctuations in the productive process can be provided by a greater worker versatility, more flexible budgets and other controls, development of fill-in products, and more storage space; industry should approve and use the decentralization idea; management is finally recognizing the many possibilities of cooperation with the supplier and the consumer; management is recognizing the employee as a coordinate human being who is realizing the necessity of doing things as cheaply as possible; and finally, there is a growing tendency in management from cold organization to a living organism.

A Note of History

Dr. L. P. Alford, past vice-president A.S.M.E., called attention to the fact that the organization of the Congress was one of the indirect results of the inquiry into waste in industry by the American Engineering Council in 1920–1921. The published report on "Waste in Industry" came to the attention of the Czechoslovakian government which asked whether a way might be found to call a conference in Czechoslovakia which would enable the government to take advantage of the report. As a result, representatives of The American Society of Mechanical Engineers and other member bodies of American Engineering Council, developed a special committee, which in cooperation with the Czechoslovakian government and the Department of State of the United States, arranged for the organization of the First International Management Congress held in Prague in 1924.

So much interest was aroused at this Congress, that a number of the nations represented at the Congress proposed that other nations organize committees of scientific management and that a second Congress be held having as its basis international cooperation in widening the understanding of scientific-management principles. In consequence, the Second Congress was held in Brussels in 1925 and there followed in order, Congresses in Rome 1927, Paris 1929, Amsterdam 1932, London 1935, and the Seventh Congress just closed, held in Washington in 1938. Stockholm, Sweden, was chosen as the place of the Eighth Congress in 1941.

Harry A. Hopf, member A.S.M.E., who was a member of the committee at the First Congress in Prague in 1924, was awarded a gold medal for his services in the interests of scientific management and, because he was "in a very real sense one of the pilgrim fathers in the international management movement."



Cushing

RIVER VIEW OF MASSACHUSETTS INSTITUTE OF TECHNOLOGY

124 Papers Presented at Fifth International Congress for Applied Mechanics

Full Program Covered Sessions, General Lectures, Receptions, and Inspection Trips

THE FIFTH International Congress for Applied Mechanics was held at Harvard University and at the Massachusetts Institute of Technology September 12–16, 1938. Some 391 persons interested in applied mechanics registered for the Congress and participated in the activities of a very full program. As this was the first time that this Congress had ever met in the United States, it is interesting to note that 87 members came from overseas. The British, French, and German delegations were especially strong.

124 Papers Presented

The sessions of the Congress included the presentation and discussion of 124 papers. Three sessions were held simultaneously, covering the fields of elasticity and strength of materials, fluid mechanics, and general mechanics, with special emphasis on vibration. There was a general lecture each day before the Congress, which assembled as a whole for this purpose.

The program outside of the time required for the professional sessions provided for a reception Monday evening to the members of the Congress by President and Mrs. Karl T. Compton of M.I.T.

Memorial Wind Tunnel

On Monday afternoon members of the Congress witnessed the dedication of the Wright Brothers Memorial Wind Tunnel.[1] Dr. Godfrey L. Cabot of the Corporation of M.I.T. was master of ceremonies and addresses were made by Mr. Griffith Brewer, representative of the Royal Aeronautical Society of Great Britain, and Dr. George W. Lewis, representative of the N.A.C.A. It was a matter of regret to many who had come from overseas that they could not meet Mr. Orville Wright who was at the last moment prevented by illness from attending. At the conclusion of the ceremony Dr. Compton turned the switch which started the wind in the new tunnel.

On Tuesday evening there was a conversazione in the laboratories of the mechanical-engineering department at M.I.T. at which some 25 exhibits in the field of applied-mechanics research were displayed. Each exhibit was attended by the member concerned with it, so that informal discussions as to methods and results were possible.

On Wednesday evening there was a reception

[1] See photograph of this wind tunnel on page 860 of this issue.

given by the Trustees of the Isabella Stewart Gardner Museum.

Thursday afternoon and evening were devoted to an expedition through historic Lexington and Concord, with a picnic supper at the Middlesex School where Dean S. C. Hollister delivered a scholarly address celebrating the tercentenary of the publication of Galileo's "Discorsi e Dimostrazioni Matematiche." After paying due respect to the memory of Galileo, the Congress assembled around a large bonfire and listened to spirituals sung by the Boston Negro Chorus.

Banquet at Eliot House, Harvard

The Congress closed with a banquet at Eliot House, Harvard University. Dean H. M. Westergaard of the Harvard Engineering School presided and the speakers were: Prof. Robert B. Merriman, Master of Eliot House, Dr. Karl T. Compton of M.I.T., Prof. L. Prandtl of Göttingen, Prof. R. V. Southwell of Oxford, and Prof. J. Drach of the Institut de France.

Visit to Washington

On Monday, September 19, a large proportion of the Congress members met in Washington at the National Bureau of Standards as guests of Director Lyman J. Briggs. The Congress members then proceeded by steamboat to Old Point Comfort where they spent the day of Tuesday as guests of the N.A.C.A. inspecting the Langley Memorial Laboratory. Dr. G. W. Lewis, Director of Research, acted as host.

Following the Langley Field visit, a smaller party proceeded to Pittsburgh to visit the research laboratories of the Westinghouse Electric & Manufacturing Company and the Aluminum Co. of America, and then on to Detroit to visit the Ford, General Motors, and Chrysler plants; and to Schenectady to visit the laboratories of the General Electric Co.

The Congress was organized by the American members of the International Committee consisting of Dr. Joseph Ames, chairman, Prof. J. C. Hunsaker, Prof. S. Timoshenko and Prof. Th. von Kármán. Dean H. M. Westergaard of Harvard acted as chairman of the Cambridge committee on arrangements for the entertainment of the visitors.

Sixth Congress to Be in Paris

A meeting of the International Committee for the Congress, met at M.I.T. on September 13 and accepted with regret the resignation of Doctor Ames as a Committee member and elected Dr. Compton president of the Fifth Congress. The Committee considered invitations for the Sixth Congress, to be held in 1942, presented on behalf of Committee Members from several countries and decided in favor of a meeting to be held in Paris under the auspices of the Faculty of Science of the University of Paris and the Société Francaise des Mécaniciens.

A.S.M.E. Applied Mechanics Division Cooperates

The Applied Mechanics Division of The American Society of Mechanical Engineers participated in the Congress, and with the approval of the Committee on Publications and the Council of the Society devoted the September issue of the *Journal of Applied Mechanics* to abstracts of all of the papers which were presented. Copies of the issue were distributed with the compliments of the Society to all those in attendance at the Congress.

American Engineering Council

Presents

The News From Washington and Elsewhere

Discussion of Public Values of Research and American Patent System at Second A.E.C. Forum

To Be Held in Detroit, Friday, Nov. 11

THE GENERAL subject of relation of research and of patents to the development of our American industrial system with special reference to the engineers' relations to them, will form the broad subject of the second Forum of the American Engineering Council, to be held in Detroit, Mich., on Friday, Nov. 11, at the Hotel Statler, with the Michigan Engineering Society as host.

Government Monopoly Inquiry

An analysis was made by the staff of American Engineering Council of the history and present status of the monopoly inquiry which may provide a basis for new Federal legislation on wages, prices, patents, and other fundamental economic industrial questions. Careful consideration of the issues involved in this "full and complete study" makes it clear that the investigation is to be more than merely anti-monopoly. It is to be a broad and all-inclusive study of any and all parts of our economic structure, the nature of their interrelationship and the manner in which they function in American present-day economy. Thus the study will extend into a careful and detailed scrutiny of virtually every aspect of management and administration policies of every great enterprise in the country. It will cover everything touching the form, structure, and function of every large business organization.

To allay apprehension on the part of business and industry, members of the investigating committee give assurance that politics will not enter as a factor in influencing the formation of their opinions and conclusions. Factual data alone, it is stated, will serve as a basis for recommendations to Congress and the President as to the best and most feasible guide policy of control and regulation of business practices within the framework of our existing economy.

Commission on Industrial-Relations Reports

Much confusion exists in our present-day thinking as to a proper labor-relations policy that will fit into the economic structure of the country. The Wagner Labor Act suffers from a great many defects. Amendments of one kind or another have been suggested and are in the process of the making. With this in view, President Roosevelt appointed a Commission on Industrial Relations to make an impartial examination on industrial relations in Great Britain and in Sweden. The Commission presented its report on Great Britain, Aug. 25, 1938, and on Sweden, Sept. 19, 1938.

The common characteristics of labor agreements and changes in wages and procedure of collective bargaining in Sweden and Great Britain as brought out in the reports are:

1 Agreements and changes in wages and hours are commonly negotiated by the national unions with employers' associations and not between a single employer or union.

2 In case negotiations on these basic subjects fail, the parties seek the help of an impartial agency, which in Sweden is commonly a government conciliator.

3 Local disputes as to application or interpretation of an agreement are first negotiated by the particular worker or his union representative and the employer. If settlement fails in this way the dispute is referred to a joint body of representatives of the national union and the employers' association. The principles underlying this procedure are the removal of the controversy from the spot of trouble and its consideration by individuals not directly concerned in it. Thus the matter may be examined, and impartial and detached judgment rendered.

4 Strikes or lockouts cannot take place while negotiation is carried on. Stoppage of work does not present any significant problem.

5 In Sweden, collective agreements are legally enforceable in the Labor Court. In England enforcement of collective agreements rests upon moral force rather than legal compulsion.

Comments on Parker Case

DR. HARVEY N. DAVIS, President of the Society has prepared a memorandum about the "Parker Case" which is available to the members upon request. The memorandum has been distributed to officers of the Local Sections and others interested.

(*A.S.M.E. News continued on page 894*)

Wherever you need a Cup-Point Set Screw that.....

STAYS PUT

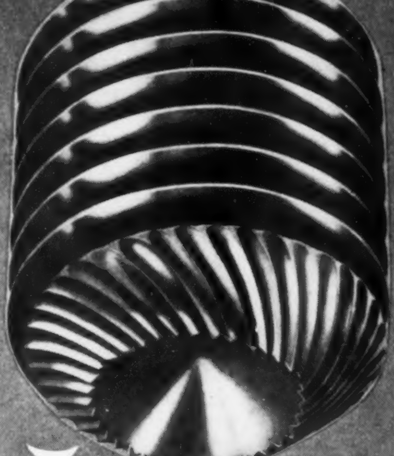


Fig. 1641
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MECHANICAL ENGINEER, graduate R. I. State College, 1938; 24, single, industrious, honor student. Well-trained in aeronautical and electrical engineering, and advanced mathematics. Eastern U. S. preferred but will go anywhere. Me-166.

MECHANICAL ENGINEER. Four years' planning, scheduling, estimating, and construction of chemical plants. Experience in layout, design, and installation of heating and air-conditioning systems. Industrial sales experience. Me-170.

MECHANICAL ENGINEER, 21, single, graduate Georgia Tech. 1938. Six-months' experience in production department of large pump company. Desires position with engineering future. Will start from bottom. Location, East. Me-171.

THERMAL ENGINEER, with over 10 years' experience in research relating to heat transfer in gases, tube and fin, insulation, and liquids. Can show that he possesses inventive and design ability to marked degree. Will go anywhere. Me-172.

FUEL AND POWER ENGINEER. Thirteen years' power-plant design, operation, maintenance, control, and supervision. Economic studies, power and steam-cost surveys, fuel selection, combustion expert. Intimate knowledge of coal, its market and use. Me-173.

MECHANICAL ENGINEER. Twenty-five years' varied experience; 17 years' chief engineer in charge of designing and constructing tar-distilling and roofing plants. Economic studies of power plants. Me-169.

GRADUATE MECHANICAL ENGINEER, University of North Carolina, age 26, single. Free to travel. Last 10 months flying with Naval Air Reserve. Desires position with aviation industry. Me-174.

MECHANICAL ENGINEER, 26, married, graduate University of Alabama, 1936. Two years' operating, testing, and maintenance of industrial power-plant equipment. Location preferred, East. Moderate salary with future. Me-175.

MECHANICAL ENGINEER, Tau Beta Pi, Georgia Tech., 1937; 26, married. One year boiler experience; 4 years' office experience. Moderate salary with future in East. Me-176.

UNDERGRADUATE MECHANICAL ENGINEER, age 22. Two years' in Newark College of Engineering. Desires connection in aeronautical field. Wants to complete training in night school or correspondence course. Me-177.

MECHANICAL ENGINEER, 36, married. Fourteen years' Diesel and hydroelectric power plants, electric distribution, machine shop, welding. Executive, construction, maintenance, and teaching. Desires position, manager, chief engineer power plant, Latin-America preferred. Me-178-3010-D-10-San Francisco.

MECHANICAL ENGINEERING GRADUATE, Michigan, 1932. Five years in meter department of electrical utility; 2 years as draftsman in research laboratory before graduation. Me-179.

GRADUATE MECHANICAL ENGINEERING, 27. Five years' experience operation, maintenance and design refrigerating, and heat-transfer (high-pressure) equipment in general; desires position with firm or consultant, New York City preferred. Me-180.

PROFESSIONAL ENGINEER, 35 years' experience England, U. S. A., manufacturing, contracting, consulting, research; experienced negotiator, witness-expert, special representative; last 4 years U. S. Government; previous 13 years large N. Y. holding company; desires change. Me-181.

GRADUATE, 1936, with good school record. Experience, railroad shop and social work. Interested in teaching, personal relations, research, advertising, utilities, management, and social work. Willing to travel. Me-182.

MECHANICAL ENGINEER, M.I.T. graduate, 21. Experience in testing steam engines, steam-turbine-driven pumps, steam pumps, steam specialties, air fans, air compressors, refrigeration units, air-conditioning units, heat-measurement instruments, etc. Me-183.

RECENT GRADUATE in mechanical engineering. Specialized in applied mathematics and design calculations. Some experience as topographic draftsman. Me-184.

MECHANICAL ENGINEER, 35. Fourteen years' design, estimating, purchasing. Textile dyeing, processing machinery; oil-refinery equipment, large refrigeration installations, power-plant apparatus. Desires position, Philadelphia area, designer, plant engineer, executive assistant. Me-185.

MECHANICAL ENGINEER, 1937 honor graduate, 23. One year experience training course of large manufacturer of steam-generating equipment. Desires position in power-plant field. Will go anywhere. Me-186.

[1] All men listed hold some form of A.S.M.E. membership.

POSITIONS AVAILABLE

MECHANICAL ENGINEER to organize mechanical-development department of acetate company. Must have inventive ability, resourcefulness, and initiative, with sufficient practical experience to have developed these traits. Experience in chemical and textile work useful, but not essential. Apply by letter. Location, East. Y-3203.

CHIEF DRAFTSMAN for development department. Must be able to supervise drafting force of about thirty, get out work quickly with no friction. Must have definite knowledge of drafting-room practice and policies, and experience with bills of material, specifications, part numbers. Duties will include rigid standards on drafting time required to do job and to schedule and check planned completion dates. Apply by letter. Location, New York State. Y-3311.

PRODUCTION SUPERINTENDENT, about 40, graduate mechanical engineer to supervise number of production engineers, as well as toolroom of approximately 300 men. Early experience as toolmaker desirable. Must have working knowledge of time-study methods and straight piecework rates. Should understand problems of associated departments, be tactful, and capable of solving problems relating to small machine production. Salary, \$6000–\$8000 a year. Apply by letter. Location, Pennsylvania. Y-3318.

CHIEF INSPECTOR who is familiar with A.S.M.E. requirements in fabrication and has technical knowledge and willingness to keep in touch and progress with art of welding and fitting of vessels. Must be diplomatic as he will come in contact with various departments, both in office and shop. Apply by letter. Location, East. Y-3332.

ADVERTISING MANAGER, young, with special leaning toward general publicity. Should be capable of conducting one- or two-man department in which much of the work would be done by himself, and possess ability to create and write publicity articles and items that merit acceptance by publications. Actual newspaper experience desirable. Must also be able to cooperate actively with sales department in marketing of products, as well as write strong, convincing English. Apply by letter. Location, East. Y-3338.

PRODUCTION ENGINEER to direct tool and die engineers. Must have time-study experience. Only engineer with this experience with hardware company will be considered. Apply by letter. Location, Pennsylvania. Y-3339.

SALES ENGINEER, 30–35, with actual experience in designing and selling machine tools. Apply by letter. Location, Middle West. Y-3352C.

WORKS MANAGER, chief engineer with experience in machine shop and mass production of jobbing machinery. Salary, \$6000 a year. Apply by letter. Location, Middle West. Y-3359C.

DEVELOPMENT ENGINEER, 30–50, for well-established manufacturing company. Must have administrative and inventive ability, and be capable of cooperating with sales department in customer contacts. Experience should include general designing and development in metal or machine industries, and working knowledge of electricity and metallurgy. Apply by letter. Location, western New York. Y-3362.

ASSISTANT PLANT ENGINEER, graduate mechanical engineer, 30–40, with at least eight years' experience in manufacturing plant in direct charge of machine maintenance, electrical maintenance, equipment installation, and machine shop. In addition, must have working knowledge of boilerhouse operation. Must have New York State Professional Engineer's license, or be able to qualify for New York State license. Salary, \$250–\$350 a month. Apply by letter. Location, New York State. Y-3363.

DESIGNING ENGINEER for centrifugal pumps.

(*A.S.M.E. News continued on page 896*)

Must have considerable experience in design of mixed-flow pumps for large capacities. Apply by letter. Location, Middle West. Y-3365C.

GRADUATE MECHANICAL ENGINEER, 35–40, to act as superintendent of steel-fabrication plant. Must be good organizer. Company manufactures steel tanks. Salary, $5000 a year. Apply by letter. Location, Pennsylvania. Y-3376.

GRADUATE MECHANICAL ENGINEER with 5 or 10 years' experience in air compressors or similar work. Company is conducting development work on new line of air circuit breakers involving the control of valves, etc., up to 300 or 400 pounds. Work will cover design of apparatus and "follow-through" in experimental stages. Apply by letter. Location, Pennsylvania. Y-3379.

PRODUCTION MANAGER, mechanical engineer, 30–35, to head production department. Experience in alloy-steel castings is essential. Salary, $250 a month. Apply by letter. Location, Pennsylvania. Y-3385.

PURCHASING AGENT, mechanical engineer with actual manufacturing and purchasing experience. Experience in metal manufacturing, forge shop, machine shop, and foundry would be very helpful. Apply by letter giving a complete chronological record of education and experience. Location, Middle West. Y-3410—R-637C.

Local Sections

Coming Meetings

Akron-Canton: November 22. Wilkes-Barre, Pa. "Aviation," by R. S. Damon of the American Airlines.

Boston: November 10. Dr. Harvey N. Davis, President of The American Society of Mechanical Engineers will address the Section members and guests on the subject "The Engineer of the Future."

Charlotte: November 11. Winston-Salem, N. C. Horace L. Smith, Jr., president and chief engineer of the Thermal Engineering Co., Richmond, Va., will be speaker of the evening, taking for his subject "Science in the Primary Handling of Tobacco."

Candidates for Membership and Transfer in the A.S.M.E.

THE application of each of the candidates listed below is to be voted on after November 25, 1938, provided no objection thereto is made before that date, and provided satisfactory replies have been received from the required number of references.

Any member who has either comments or objections should write to the secretary of The American Society of Mechanical Engineers immediately.

KEY TO ABBREVIATIONS

Rt = Reinstatement; Re = Reelection; Rt & T = Reinstatement and Transfer to Member

NEW APPLICATIONS

For Member, Associate, or Junior

ANGUS, WILLIAM JOHN, New York, N. Y. (Rt)
BABCOCK, WILLIAM W., Peoria, Ill.
BROAN, A. J., Dallas, Tex.
CORWIN, LLOYD ALBERT, Milwaukee, Wis.
CREECH, MERL D., Oklahoma City, Okla.
ECK, KNUT E., South Gate, Calif.
ELKINS, DOUGLAS A., Salt Lake City, Utah
EXLEY, L. M., Valley Stream, L. I.
FORD, JOHN HENRY, Chicago, Ill.
FRENCH, JOHN C., Balboa, C. Z. (Re)
GAREN, DONALD R., East Moline, Ill.
HOPKINS, EDW. J., Chicago, Ill.
HORTON, ELWOOD, New York, N. Y.
HUBER, ERNEST W., Oakland, Calif. (Rt)
JACKSON, L. B. W., Channing, Tex. (Rt & T)
HYATT, R. S., Ivorydale, Ohio
KUT, WALTER S., New York, N. Y.
MACCONE, CHESTER L., Oakland, Calif.
MARNY, R. C., New York, N. Y.
McDONALD, J. E., East Chicago, Ind. (Rt)
McLEAN, WM. G., Easton, Pa.
MORELWAR, D. N., Sholapur, India
MURRAY, J. R., Barberton, Ohio
NICHOLS, CHAS. R., JR., Jersey City, N. J.
SNYDER, NORMAN S., Buffalo, N. Y.
WEHMHOFF, BYRON L., Chevy Chase, Md.
WEST, HOWARD F., Cleveland, Ohio

CHANGE OF GRADING

Transfer to Fellow

MALEEV, V. L., Stillwater, Okla.

Transfers to Member

BALLIN, ALFRED E., Tulsa, Okla.
LAWRENCE, ARTHUR T., New York, N. Y.
MARKER, ROLAND H., Toledo, Ohio
PARKER, R. STARR, Cincinnati, Ohio

Necrology

THE deaths of the following members have recently been reported to the office of the Society:

ADAMS, ARTHUR H., September 25, 1938
AHLQVIST, HARALD, September 6, 1938
BERGQUIST, JOHN G., August 30, 1938.
BOLTWOOD, HARVEY, September 2, 1938
DOUGLAS, JOHN R., April 4, 1938
HURLBURT, RUSSELL B., July 17, 1938
McMILLIN, FRANK B., September 8, 1938
O'TOUSA, MICHAEL, June 20, 1938
PEYSER, JOSEPH, April 4, 1938
RUSH, CHARLES W., September 24, 1938

A.S.M.E. Transactions for October, 1938

THE October, 1938, issue of the Transactions of the A.S.M.E. contains the following papers:

TECHNICAL PAPERS

The Fundamentals of the Design of Cracking Furnaces (FSP-60-18), by A. L. Baker, J. H. Rickerman, and W. E. Lobo

The Distribution of Energy in the Pulverized-Coal Furnace (FSP-60-19), by W. J. Wohlenberg and D. E. Wise

Industrial Applications of Spiral Bevel Gears and Hypoid Gears (MSP-60-1), by A. H. Candee

Problems in Modern Deep-Well Pumping (PME-60-2), by C. J. Coberly

The Drafting of Steam Locomotives (RR-60-4), by J. R. Jackson

DISCUSSION

On previously published papers by Messrs. A. I. Lipetz; Ed S. Smith, Jr., and C. O. Fairchild; William Hovgaard; K. J. DeJuhasz; S. A. McKee and T. R. McKee; E. B. Strowger; A. A. Potter, H. L. Solberg, and G. A. Hawkins; and L. M. C. Wegner

1938 A.S.M.E. Memorial Biographies Sent on Request

MEMBERS of The American Society of Mechanical Engineers who wish to receive a copy of the 1938 Memorial Biographies of Deceased Members are requested to fill out and mail the accompanying form, or order by letter, addressed to the Secretary, A.S.M.E., 29 West 39th Street, New York, N. Y.

These Memorial Biographies, which were published in October, will form a part of the Society Records Section of the Transactions as bound for library use. They memorialize the lives of 132 members of the Society deceased within the last few years, in most cases prior to 1937. Memorials of those who have died more recently are now in preparation. These will appear next year or later, depending on ability to assemble within the time allowed all of the necessary details, some of which are secured under great difficulties.

A.S.M.E.
29 W. 39th St.
New York, N. Y.

Please send me a copy of the October, 1938, issue of Memorial Biographies.

NAME..............................

ADDRESS..............................

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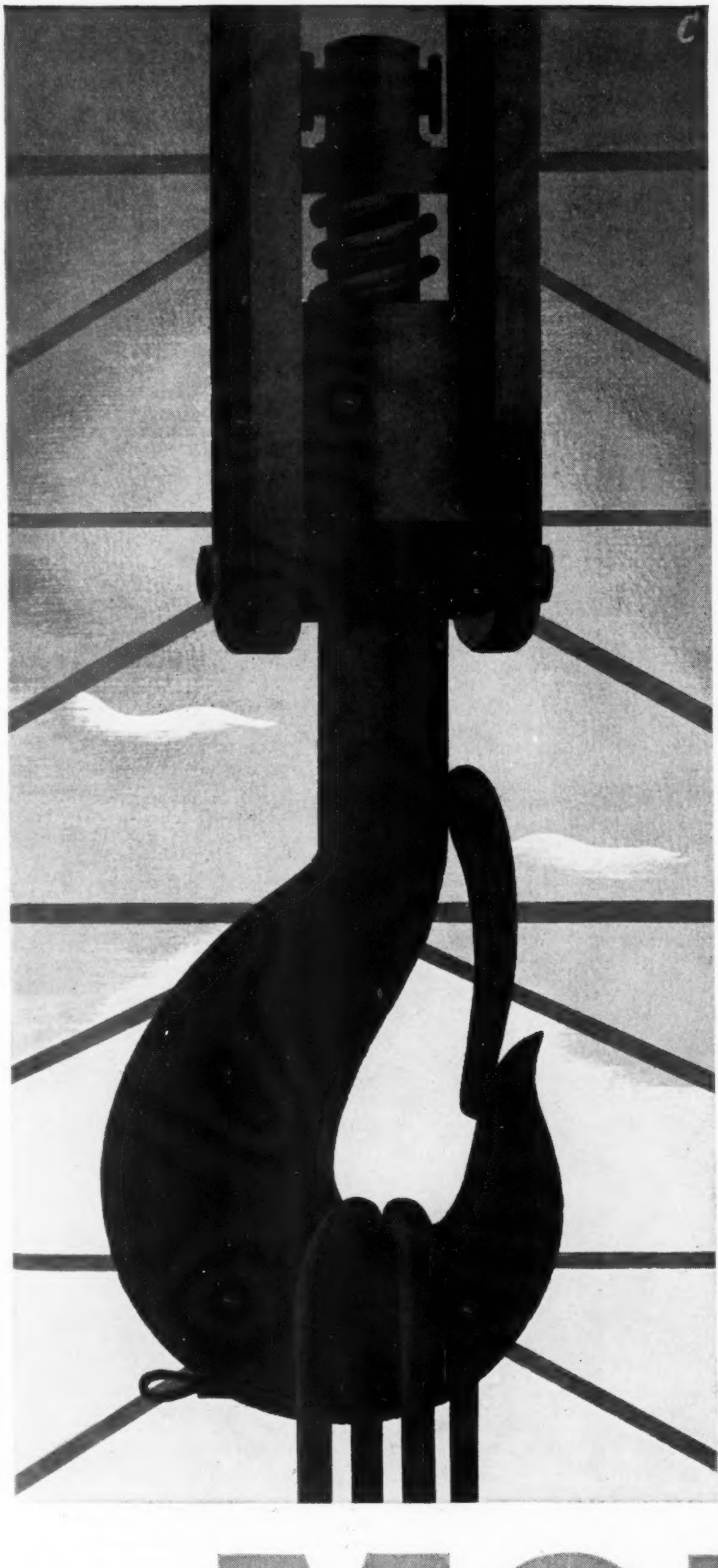


•Keep Informed . . .

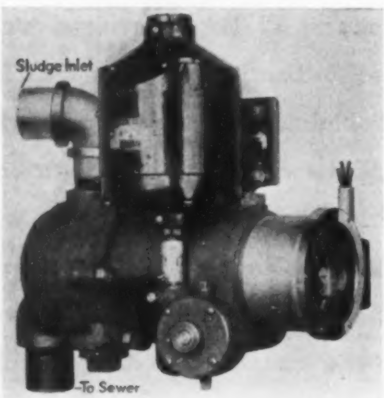
Available literature may be secured by addressing a request to the Advertising Department of MECHANICAL ENGINEERING or by writing direct to the manufacturer and mentioning MECHANICAL ENGINEERING as the source.

• NEW EQUIPMENT
• BUSINESS CHANGES
• LATEST CATALOGS

Announcements from current advertisers in MECHANICAL ENGINEERING and the MECHANICAL CATALOG

• NEW EQUIPMENT

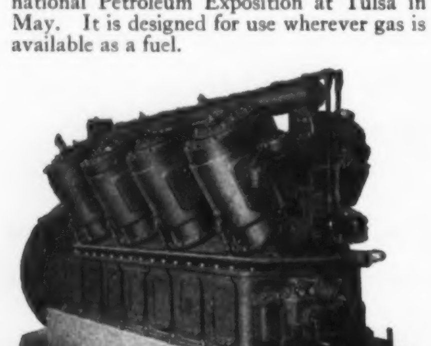
Automatic Desludging Valve



New automatic desludging valve. Developed as a part for its hot process lime soda water softener in which sludge must periodically be removed from a settling tank, The Permutit Co., 330 West 42nd St., New York, N. Y., has placed upon the market an automatically operating valve for permitting the flow of sludge from a container by gravity or under pressure. Automatic operation of such a valve is highly desirable because periodic desludging by hand is apt to be overlooked or postponed for such an interval as to impair the efficiency of operation. With automatic desludging this is accomplished under precise control, assuring uniform conditions. The valve is motor operated and of simple construction. Booklets are furnished upon request.

New Gas Engine Bulletin

A new bulletin has been issued by Ingersoll-Rand describing the Type PVG gas engine, shown for the first time at the International Petroleum Exposition at Tulsa in May. It is designed for use wherever gas is available as a fuel.



The PVG engine is a logical development to supplement the popular XVG gas-engine-driven compressor introduced by this company in 1932. It is a 4 cycle, V-type, multi-cylinder engine, built for continuous full load operation at the moderate speed of 400 RPM. Available in three sizes of 4 cylinder 185 hp., 6 cylinder 275 hp. and 8 cylinders 370 hp., it has the same cylinder arrangement and cylinders as the XVG, and is manufactured in the same plant with the same jigs and tools.

Installations of PVG and XVG units total nearly 150,000 hp., attesting not only the popularity of this design but its dependability in service. The PVG engine provides economical power for driving centrifugal pumps, blowers and generators, as well as existing line shafting or machinery.

Copies of the bulletin 10,011 may be obtained from Ingersoll-Rand Company, 11 Broadway, New York, N.Y., or any of their branch offices.

Automatic Control for Reeves Motodrive

Reeves Pulley Co., Columbus, Ind., announces the development of Mechanical Automatic Control for the REEVES Motodrive, which greatly increases the utility of this unit.

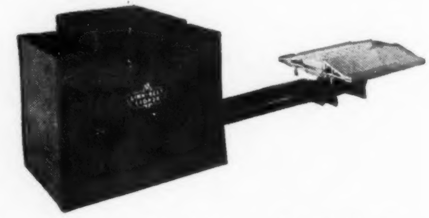
The Motodrive itself—a modern variable speed control unit combining speed control mechanism, motor and gear reducer in one assembly—is well known to industry. The Mechanical Automatic Control provides entirely automatic speed regulation of the Motodrive to make possible synchronization of different machines and separate sections of a single machine; maintenance of constant tension and uniform peripheral winding speeds; and maintenance of uniform pressure, weight, liquid level, temperature and other variable elements. This control is distinguished by ruggedness and simplicity of design and construction, and its nearly 100% "fool-proof" operation.

On the motor (constant speed) shaft of the Motodrive is a cover plate including a lever bracket and extended lever which may be attached by cable or chain or direct to a compensating or floating roll (where properly balanced by weights), pressure regulator, moving carriage or part of machine, etc., from which indication of required speeds can be taken. Movement of the lever is transmitted to the speed changing mechanism of the Motodrive to change its speed in accordance with the indicating movement, thus providing the advantages in automatic control cited above.

Travel of the lever in either direction is limited by stop screws. The lever may be of any length, as required by the installation, and may be assembled in any one of four different positions. The control is available for all five sizes of Motodrive, both horizontal and vertical designs.

New Stoker Model Announced by Link-Belt

A new model commercial stoker, designated as the No. 15, has been put on the market by Link-Belt Company, of Chicago. It is designed to burn a wide variety of bituminous stoker coals, and will handle 3,500 sq. ft. of radiation.



The hopper is entirely enclosed; the front compartment housing the fan, motor, transmission and Air-Meter (automatic air control). The shear pin on the transmission is equipped with a "Load-Signal," which announces when the pin shears, in case an obstruction should get into the feed tube.

The burning head is the "Power-Flex" type, which features laminated tuyeres with primary and secondary air ports. No dead plates are used. With this design, an active fuel bed is maintained over practically the whole area of the furnace; with consequent higher efficiency and capacity. The Power-Flex head will burn both low-fusion, non-caking bituminous coals and high-fusion, caking and coking coals. Flexibility to meet local boiler conditions is secured by the use of various length tuyeres.

Further information may be had by addressing Link-Belt Company, 2410 W. 18th Street, Chicago.

New G-E a-c Arc Welder for Light-Gage Work

A new 150 ampere alternating current arc welder of the transformer type has been developed by General Electric Co., Schenectady, N. Y., for low current welding with heavily coated alternating current arc welding electrodes. While it is chiefly intended for use on light-gage metals, its wide welding range—35 to 180 amperes—permits its use on fairly heavy materials as well.

With this type of equipment, power costs are reduced approximately 50 per cent as compared to welders of the rotating type. In addition, it avoids troublesome arc blow, sometimes experienced with direct current welders, thus reducing the number of rejects to a considerable extent and avoiding the necessity of reworking welds.

The new equipment is built with woven, spun-glass, fireproof insulation which prevents damage from heat on heavy overloads. Solidly brazed internal connections eliminate the possibility of open circuits. Continuous, stepless current control is obtainable by means of a hand-crank. This arrangement gives accurate adjustment of the welding current to suit fine work. Adjustment can be obtained at any time without interrupting the arc or opening any electrical connections.

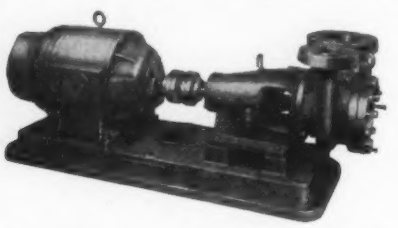
Continued on Page 18

A choice of two open-circuit voltages (80 and 100 volts) is provided to handle all types of a-c electrodes. The welding lead can be quickly and easily connected to either tap by means of a taper-bored connector. A circular cover plate over the terminals prevents chance contact with the terminal (or terminals) not being used. Easy portability is provided by casters or by means of a hoist sling over the hand-crank.

The equipment meets the rigid requirements of the latest standards of Underwriters' Laboratories, Inc., and is listed under their Re-examination Service.

New Refinery Process Pumps

A new series of refinery process pumps known as the Class FH and FL has been announced by the Ingersoll-Rand Company. Built in capacities to 800 GPM and heads to 400 ft., these pumps are designed for such



refinery processes as those in which hot oils, distillates, bottoms, cold oils, propane, butane, solvents, etc., are handled. They will handle fluids at any temperature and are constructed for continuous operation on severe service.

The pump is supported by an extra heavy *one* piece cradle which combines the connecting piece, the bearing housing, and a water-jacketed oil reservoir.

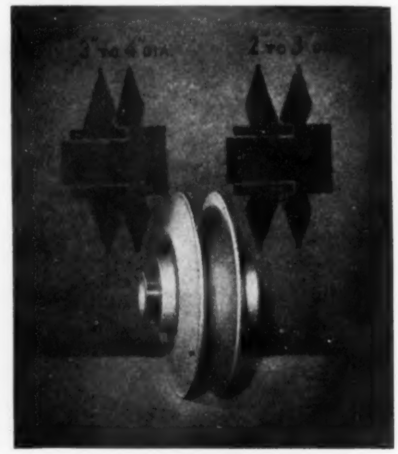
Its design is such that suction and discharge connections are integral with the casing. They open vertically and are therefore self-venting. Positive lubrication of the bearings is effected by rotary discs, the oil being contained in a large water jacketed reservoir and circulated to secure thorough cooling. The stuffing box is likewise water-cooled, reducing heat transfer to the pump shaft and bearings. It is extra deep to receive a sealing cage if conditions warrant. Wearing rings on the impeller permit the renewal of worn parts with standard parts from stock.

Descriptive literature is contained in bulletin 2432, copies of which are obtainable from Ingersoll-Rand, 11 Broadway, New York, N.Y., or any of their branch offices.

The 2-3-4 Single Groove Adjustable Sheave

The Texrope Division, Allis-Chalmers Manufacturing Company, Milwaukee, Wisconsin has developed something new in an Adjustable Texsteel Sheave, truly a combination sheave for double duty. This sheave has a range of pitch diameter varying from 2″ to 3″, and from 3″ to 4″ by merely removing the adjustable plate, reversing and again placing on the hub.

As shown in the picture, the outer plate in the position shown at left allows the Texrope Belts to ride high and give a pitch diameter anywhere from 3″ to 4″; the outer plate reversed in the position shown at the right allows the Texrope Belts to ride low and give a pitch diameter anywhere from 2″ to 3″; the two together providing for a speed variation



of 100%. This change takes but a moment.

This sheave has been developed in response to a demand for a sheave that is low in cost and yet has a wide range of speed variation. It is especially well suited to the heating and ventilating industry. This new sheave makes use of the now famous Duro-Brace principle of construction, which is accepted as the most rigid, sturdy, true-running sheave in the field.

• BUSINESS CHANGES

Inland Licenses Carnegie-Illinois Steel Corp. to Make Lead-Bearing Steel

Inland Steel Company has licensed the Carnegie-Illinois Steel Corp. to produce its new lead-bearing steels, according to an announcement made at the Inland offices today. The development of lead-bearing steel was first announced by Inland in May of this year. The new steel has been produced in hot rolled form under the trade name, Ledloy, and has been cold finished by a number of cold drawing firms. It is expected that Inland will license other steel companies in the near future. The outstanding advantage of the product is its easy machinability, which results in important savings both in machining time and in lengthened tool life.

21-Year Old Morse Chain in Good Operating Condition

Interesting examples of the long-lived performance of Morse Silent Chain drives crop up periodically. The most recent one is that of the Updike Grain Elevator, Council Bluffs, Iowa, in which a $7,200.00 Morse installation, made by the contracting firm of Witherspoon, Englar Co., 21 years ago, is now being completely reconditioned for many more years of service, at a cost of approximately $2,000. This is the only major expenditure for chain replacements in this elevator during this 21 year period. An order for this amount has now been placed with the Morse factory by the Chicago Northwestern Railway Company, owner of the Updike Elevator.

There are 42 drives all told, totalling approximately 1500 horsepower, on elevator

Continued on Page 20

• Keep Informed
Continued from page 18

legs, countershafts, belt and screw conveyors, shovel drives and cooler fans.

On seven 100-horsepower drives on shipping and receiving legs, three new chains were required. The remaining chains and all of the sprockets have been found in good condition, capable of many more years of service. On the 42 drives, 16 new chains and five sprockets are being supplied.

This service record is all the more outstanding in view of the fact that a large percentage of the original drives has been operated all these years without cases, and while grain elevator dust is less harmful than many other types of foreign matter, it still (to quote W. W. Bertram, Morse Sales Manager) "leaves much to be desired as a lubricant." While practically all of the drives were in operating order, those which were inclosed were in much better condition.

It is doubtful that any other type of drive would have given the same service with so small upkeep and so few replacements after such an extended period of service.

• *LATEST CATALOGS*

Life Expectancy of Mechanical Equipment

Engineers and equipment manufacturers, in general, will be interested in a new bulletin B-100 just issued by Lubriplate Division Fiske Brothers Refining Co., 107 Monroe St., Newark, N. J. In this bulletin entitled: "Life Expectancy of Mechanical Equipment" is clearly brought out the importance of proper and long lasting lubrication not only for initial application but also after it gets into the hands of the user. Whether the machine be an electric razor or the heaviest steam hammer, its proper lubrication is paramount.

Sullivan Air Compressors

The Sullivan Machinery Company of Michigan City, Indiana, has released an attractive new twenty page catalog, Bulletin A-22, describing and illustrating their Unitair stationary and semi-portable air compressors. A number of refinements and improvements has been made to this popular line of compact, two-stage, air-cooled compressors including the addition of a larger size (435 cubic feet per minute displacement), the use of force feed lubrication and the design of a simplified automatic stop and start control for motor driven styles. The new bulletin fully describes these improvements and also covers power unit driven types. The current Unitair compressor is available for displacements ranging from 107 to 435 cubic feet per minute and for commercial pressures up to 125 lbs. per square inch.

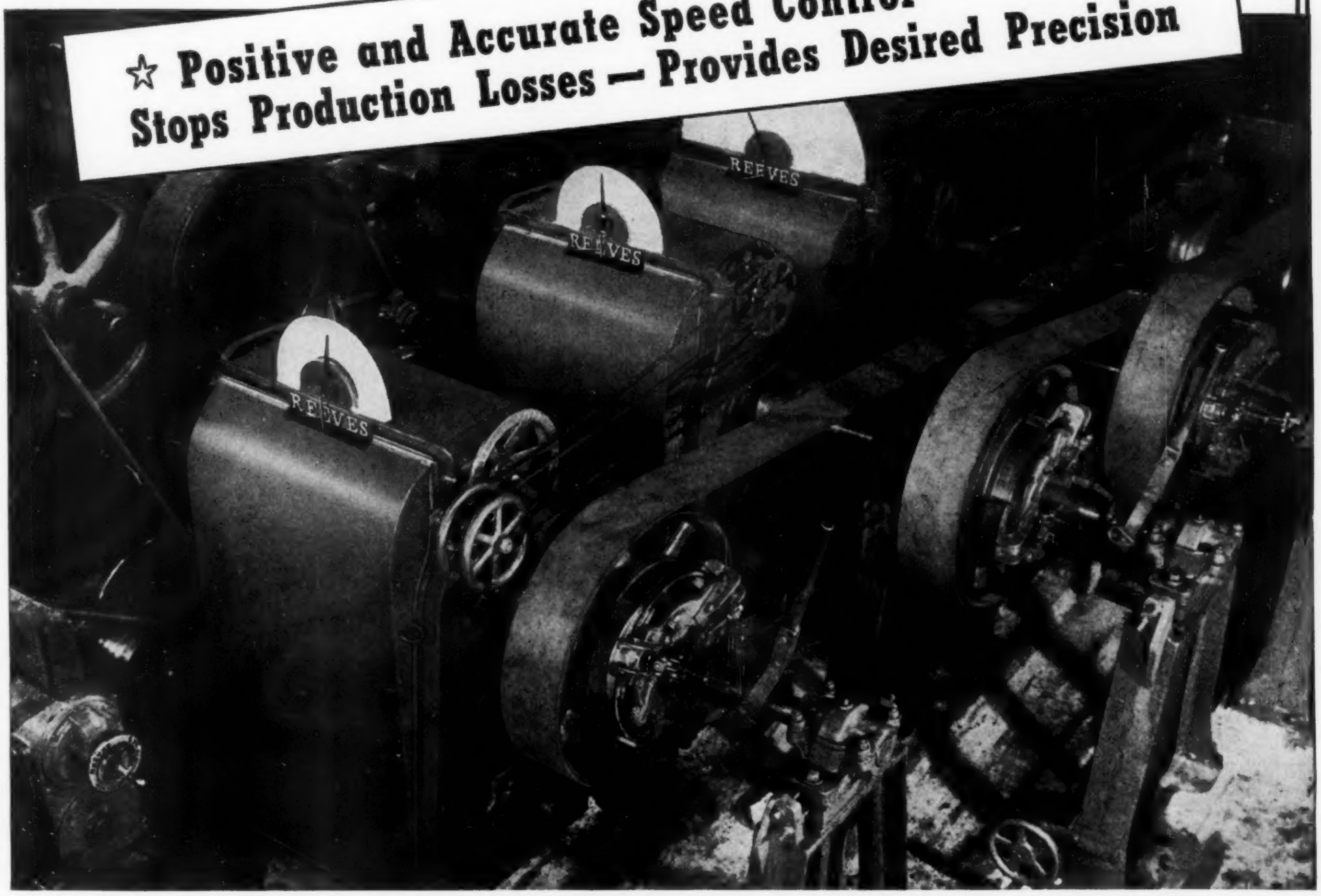
Convertible Slip Ring Motors

Bulletin M-2, "P & H Convertible Slip Ring Motors," is the most recent addition to the group of Harnischfeger electric motor catalogs. Giving a thorough analysis of the requirements demanded of the standard wound rotor type of slip ring motor, this booklet includes specific information describing how P & H motors are designed and manufactured. Bulletin M-2 describes also the standard conversions for four types of service possible with P & H Convertible Slip Ring Motors, namely, Splash-Proof, Dust and Weather-Proof, Enclosed Fan-

Continued on Page 22

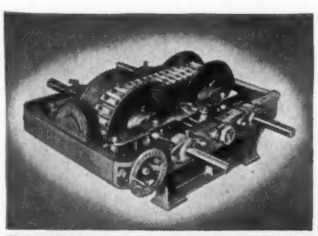
WHEN *"A MISS IS AS* BAD *AS A MILE"...*

☆ Positive and Accurate Speed Control Stops Production Losses — Provides Desired Precision

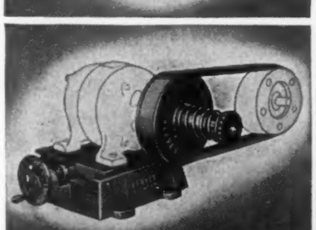


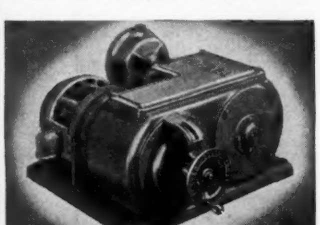
● In the operation of many machines, speed variation is not only essential, but it must be *absolutely accurate*—otherwise materials are wasted, quality or quantity of production lost, additional operations made necessary.

On such work, it is literally true that "a miss is as bad as a mile." Even *slight* slippage or fluctuation in speed is costly.



In operating the paper board cutter shown above, at Mac Sim Bar Paper Co., Otsego, Mich., greater accuracy was required in cutting dimensions of sheets. On the longest lengths, it was impossible to hold the sheet within ¾-inch plus or minus of the required length. This called for an extra trimming operation on a press cutter. Three REEVES Variable Speed Transmissions were then installed to drive the three fly-knives and draw rolls; also a REEVES Motodrive to drive the carrier roll.





Now, sheet length is held within 1/16-inch plus or minus of desired length, waste of paper in the press cutter is eliminated and this extra operation is saved.

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Continued from page 20

Cooled and Standard types. With cross-sectional line drawings and complete description of the salient features of the stator, the rotor, the slip rings, brush holders and the P & H Solenoid operated brakes, this bulletin will be of interest to motor users in industrial shops, machine shops, steel mills, and all other branches of industry where motors with controlled starting and speed regulation are required. Copies may be obtained by writing the Harnischfeger Corporation, 4497 W. National Ave., Milwaukee, Wisconsin.

Properties and Uses of Inconel

Revised edition of Bulletin T-7 just issued by The International Nickel Co., 67 Wall St., New York, N. Y., contains many changes from the preceding edition. The text has been rearranged and, in many parts, rewritten extensively. Revisions and additions have been made in the tables of "Physical Constants" and "Mechanical Properties." The latter has been expanded greatly. Two graphs showing the relationships among physical properties at normal temperatures have been added.

New data on short-time, high-temperature tensile properties have been plotted (Fig. 3), and a graph of short-time and long-time high-temperature strength has been omitted from the sub-section on "High-Temperature Properties." A limited amount of new creep test data has been added. There are added sub-sections on compression, shear, torsional and fatigue properties, and the sub-section on spring properties has been rewritten.

The section on "Corrosion Resistance" has been revised completely and brought up to date. The section on "Working Properties" has been revised in several places. The most notable change is in recommended practice for pickling; an entirely new procedure is given. There are revisions in the sub-sections on "Rolling and Drawing" and "Joining." The latter contains changed recommendations for silver soldering. A more comprehensive set of data is given in the table of "Physical Properties of Inconel Welded Joints." The section on "Typical Uses" has been brought up to date.

Three illustrations have been omitted and one in Plate II (exhaust manifold) has been changed for a more recent illustration. There are two added illustrations—Fig. 8, showing an Inconel exhaust manifold for airplane engines, and Fig. 10, showing a motion picture film developing machine.

SS Unit Close Coupled Centrifugal Pumps

Allis-Chalmers Manufacturing Co., Centrifugal Pump Division, Milwaukee, Wis., has come out with a new bulletin 1653 on their line of close-coupled centrifugal pumps covering a range of 10 gpm against 10′ head to 1600 gpm 120′ head, and for lower capacities up to 300′ head. It includes capacity tables showing ratings obtainable and recommended motor sizes and speeds for various ratings. It also describes their single suction, base mounted pumps suitable for texrope, flat belt, or direct connection to gasoline engines or steam turbines. It includes dimension sheets and useful data in figuring pump installations.

Metameter System of Telemetering

The Bristol Company, 21 Bridge Street, Waterbury, Connecticut, announces the publication of a 24-page bulletin covering the Metameter System of Telemetering. In this publication detailed engineering information is given on the subject of telemetering instrument readings. The various models available for remote measurement and automatic control of pressure, vacuum, liquid level, temperature, flow, voltage, current, load and totalized power load are illustrated.

This new bulletin is complete with line drawings to plainly show the principle of operation of Bristol's Metameter, and the method of installation. A few of the hundreds of Metameter Systems now in operation are pictured and described, to indicate its many practical uses in process manufacturing, and in the distribution of gas, water, steam and electricity.

Bulletin No. 515 is a comprehensive booklet on the subject of Telemetering that will be of great value for the reference files of every operating and supervising engineer.

De Laval Pumps

The City of Dallas, Texas, after many emergencies in respect to water supply, caused by rapid growth of population and including even dry spells when the daily supply for homes was at times delivered by water wagons to tubs at the curb and other extreme measures, now has behind the new Lake Dallas Dam sufficient water for fire protection and for commercial and domestic use to outlast, it is estimated, four rainless years; also adequate distribution and pumping facilities. The history of this development is recounted in a pamphlet "De Laval Pumps at Dallas, Texas," published by the De Laval Steam Turbine Co., Trenton, N. J., builders of the pumps. Copies of the leaflet will be sent upon request to water works officials, engineers and others interested.

COMING MEETINGS AND EXPOSITIONS

For the next three months

NOVEMBER

9–11	American Institute of Chemical Engineers, Philadelphia, Pa.
14	Society of Automotive Engineers, Annual Dinner, Commodore Hotel, New York, N. Y.
14–18	American Petroleum Institute, 19th Annual Meeting, Stevens Hotel, Chicago, Ill.
17–19	National Machine Tool Builders' Association, Fall Meeting, Hotel Homestead, Hot Springs, Virginia.

DECEMBER

1–2	Society of Naval Architects and Marine Engineers, 46th Annual Meeting, Waldorf-Astoria Hotel, New York, N. Y.
5–9	The American Society of Mechanical Engineers, Annual Meeting, New York, N. Y.
6–8	American Society of Refrigerating Engineers, 34th Annual Meeting, Hotel Commodore, New York, N.Y.
27–28	Institute of Aeronautical Sciences, Technical Meeting, Richmond, Va.
27–31	American Association for the Advancement of Science, Winter Meeting, Richmond, Va.

JANUARY 1938

9–13	Society of Automotive Engineers, Annual Meeting, Detroit, Mich.
15–17	National Aeronautic Association, Annual Convention, St. Louis, Mo.
18–21	American Society of Civil Engineers, Annual Meeting, New York, N. Y.
23–26	American Society of Heating and Ventilating Engineers, Annual Meeting, William Penn Hotel, Pittsburgh, Pa.
23–27	American Institute of Electrical Engineers, Winter Convention, New York, N. Y.
23–27	Institute of the Aeronautical Sciences, Annual Meeting, Columbia University, New York, N. Y.

The Standards COLUMN

News of Interest to Manufacturers

Steel Pipe Flanges and Flanged Fittings

THE final formal approvals of the second revision of the American Standard for Steel Pipe Flanges and Flanged Fittings are now in process. This revision was begun in the spring of 1936 and was completed in the spring of this year.

In its new form this standard is just double the size of the 1932 edition. In addition to the normal corrections and changes in the text this revision contains the following important improvements:

1 Tables of dimensions for the 2500 lb series of steel pipe flanges and fittings.

2 A complete set of tables of dimensions of welding neck flanges and fittings for all pressures.

3 All details of welding bevel for all welding neck flanges and wall thickness of pipe.

4 A complete set of dimensions for slip-on welding flanges for 150 and 300 lb pressures.

5 Complete dimensions for blind flanges for all pressures.

6 Bolt lengths for flanges of all pressures, types, and sizes.

7 Detailed dimensions for ring joints designed for 150, 300, 400, 600, 900, 1500, and 2500 lb pressures. These are the ring joints originally designed for use in the petroleum industry by committees of the American Petroleum Industry.

8 Extensive revision and expansion of the temperature-pressure ratings which were originally issued as an addenda to the 1932 edition. These tables now cover both the use of carbon steel and carbon-molybdenum and equivalent alloy steels. They also take account of ranges of primary service pressure ratings from 150 to 2500 lb and ranges in temperature from 100 to 1000 F.

9 A table has been added giving the dimensions of reducing screwed flanges for pressures of 150 to 2500 lb.

10 The introductory notes have been expanded to include explanatory material covering each of these additions.

11 Finally to assist the user of this standard a detailed index containing many cross references is to be added to the booklet when finally published.

This activity has been under the auspices of the Sectional Committee on the Standardization of Pipe Flanges and Flanged Fittings (B16) of which Dr. Collins P. Bliss is chairman, Mr. John J. Harman is secretary, and on which Mr. Arthur M. Houser acted as chairman of an informal editing committee. The three joint sponsors for the project under the procedure of the American Standards Association are the Heating, Piping and Air Conditioning Contractors National Association, the Manufacturers Standardization Society of the Valve and Fittings Industry, and The American Society of Mechanical Engineers.

For further information—address
The American Society of Mechanical Engineers
29 West 39th St., New York, N. Y.